NC STATE UNIVERSITY
JTATM
Journal of Textile and Apparel, Technology and Management

Volume 7, Issue 3, Spring2012

Performance Analysis of Ultrafine Denier Nonwoven Produced Through Pie-wedge Split Technique in the Development of Active Wear

R. Ramachandran
P. Kanakaraj
Assistant Professors
Department of Fashion Technology, PSG College of Technology
Coimbatore, 641004 India

ABSTRACT

Comfort is a necessity of for all sportsmen during play resulting from wicking and absorption properties of the textile materials. The nonwoven fabrics in general have good absorption characteristics, but their poor strength is a barrier for usage in apparel. Selection of ultrafine denier nonwoven provides a possibility in making of sportswear through nonwoven. Sportswear using ultrafine denier nonwoven has been developed to provide better comfort through greater absorption and wicking of sweat from the body surface to the environment. The ultrafine denier nonwoven fabrics produced from polyester and Nylon 6 blend (70/30) of 130 g/m^2 and 170 g/m^2 have been selected for making the sportswear. These fabrics were dyed using disperse dye. The perspiration level of different parts of the body is studied and the sportswear is designed based on the study results. The ultrafine denier nonwoven fabrics were used in the design of the garment where the human body is prone to have higher perspiration level. The fabrics were evaluated for their mechanical and comfort characteristics, namely, tensile strength and elongation, abrasion resistance, stiffness, air permeability, water absorption, moisture vapor permeability and wicking and compared against that of 100% knitted fabric of similar areal density used for sportswear. Statistical analyses were performed for the significance of their differences.

Keywords: comfort, nonwoven, sportswear, polyester/nylon blends, ultrafine denier fibers

1.0 INTRODUCTION

Use of textile fibers and fiber products has increased significantly in recent years as sportswear, sport equipment and sports footwear. The sportswear and sports goods sectors of the textile industry have seen not only market diversification but also elevated textile science and technology to a level matching that of other high-tech industrial sectors[1]. At the same time, the new technological development for the highly fragmented niche markets and the ever increasing customer expectation drive relentlessly these industrial sectors for continuous changes. In order to thrive in this environment, companies are implementing radically new product development practices. The global market volume for sportswear varies depending on the type of end use applications. High value products exist at the upper end of the price scale, at low volumes, and these are very specialized products where performance, quality and design, and not price, seem to be the determining factors. The sportswear market occupies an important place in the total textiles scene and this segment of the textile market is growing at a high rate. The producers of sportswear and sports goods have been concentrating their efforts on improving their strategic position, productivity, added-value product assortment and niche positions in order to expand their markets. This study aims to incorporate Ultrafine Denier Nonwovens in developing active wear for better performance of the wear.

2.0 MATERIALS AND METHODS

Polyester / Nylon 6 (70/30) ultrafine denier fiber nonwoven produced by sea in island technique of 130 GSM and 170 G/M2 were sourced from M/s. FREUDENBERG, Germany. The nonwoven fabric was dyed using disperse dyes and the conditions at dyeing process was given in table 2.1 and fig. 2.1. The dyed material was used for constructing the active wear. Polyester/cotton (37/63) knitted fabric of 170 G/M2 which is used for developing the commercial sportswear was sourced from M/s. EXIM KNITS, Tirupur, India. The perspiration level of different parts of the body is studied and the sportswear is designed based on the study results. The Ultrafine denier nonwoven fabrics were used in the design of the garment where the human body is prone to have higher perspiration level. The following are the sample details.

Sample A - Ultrafine denier fiber nonwoven fabric of 170 g/m^2
Sample B - Ultrafine denier fiber nonwoven fabric of 130 GSM
Sample C - Knitted fabric of 170 g/m^2

Table 2.1 Dyeing Process Conditions

Machine	**Airflow**
Model	**THEN - AFE**
Temperature	**130^o C**
Time	**30 mins**
Overall batch time	**4 hrs**
MLR	**1:4**

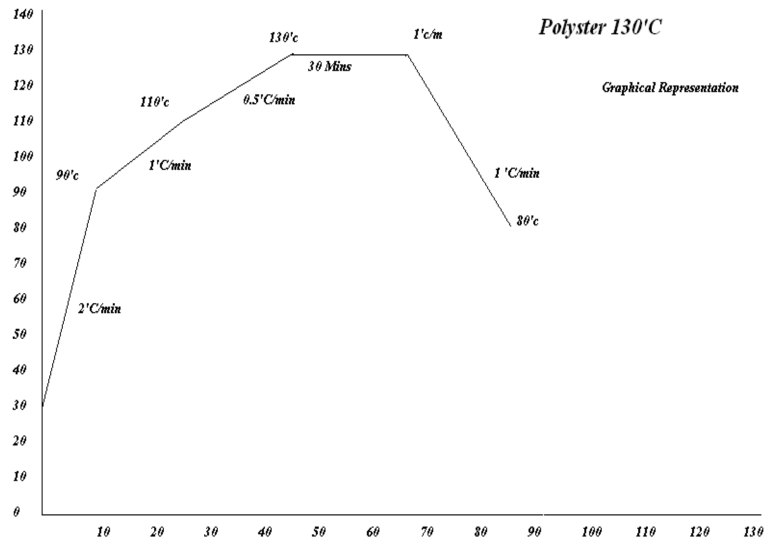

Fig 2.1 Dyeing – Time and Temperature chart

Fig 2.2 Knitted garment

Fig 2.3 Ultrafine denier Nonwoven garment

Sportswear applications demands high sweat absorption, provide comfort to the wearer, and withstand stretch and strain caused during intensive sports activity. In addition the product should also offer good breathability, resistant to surface abrasion and possess reasonable strength. Hence the following parameters were assessed to compare ultrafine nonwoven and knitted fabric samples.

- Water Absorption
- Longitudinal and Lateral Wicking
- Air Permeability
- Water vapor permeability
- Tensile strength & Elongation
- Abrasion Resistance & Stiffness

The samples were conditioned in a standard atmosphere of 65% relative humidity and 20^{o} C +/- 2^{o} C for at least 24 hrs. prior to the testing and standard test procedures were followed for testing the samples.

Subjective evaluation is also made to analyze the performance of the sportswear produced from both the knitted and nonwoven materials. After playing basketball, the subjects were asked to evaluate the garment on a four point evaluation scale; as mentioned below.

- 1- Poor
- 2- Satisfactory

- 3- Good
- 4 – Excellent

The results were interpreted and the significant difference between the sample results were analyzed using single factor ANOVA followed by the post HoC Tukey HSD test using the formula:

$$q = \frac{\overline{X}_i - \overline{X}_j}{\sqrt{\frac{s_W^2}{n}}}$$

Where,
S^2_W = Mean square deviation – between samples
n= number of samples

3.0 RESULTS AND DISCUSSIONS

The average values* for the tested characteristics were tabulated in the table 3.1.

Table 3.1 Assessment of various performance parameters

PARAMETER		Unit	Sample A	Sample B	Sample C
Absorption Characteristics	Rate of Absorption	cm / sec	0.019	0.023	0.021
	Total Absorption Capacity	g / g	2.71	2.68	2.15
Wicking Characteristics	Longitudinal Wicking	g.cm	4.95	1.89	1.47
	Transverse Wicking	cm^2 / sec	52.3	66.45	43.08
Air Permeability @ 10 cm water head		cc / sec / cm^2	62.3	62.08	191.23
Water Vapor Permeability		g / m^2 / 12 hrs.	3.958	4.13	7.506
Strength Characteristics	Tensile	Kgf / mm^2	2.11	1.55	1.16
	Elongation	%	45.52	42	89
Abrasion Resistance (Difference in mass)		g	0	0	0
Stiffness	Bending Length	cm	2.68	2.15	0.69
	Bending Modulus	Kg / cm	17.21	32.04	0.355
	Flexural Rigidity	mg. cm	309.81	124.6	6.39

*** Values indicated are average results of five readings**

3.1 Absorption

The absorption characteristics in terms of rate of absorption and total absorption capacity of the three samples were studied and presented in the figs. 3.1. The rate of absorption is largely characterized by the extent of transport of liquid in to an absorbing material.

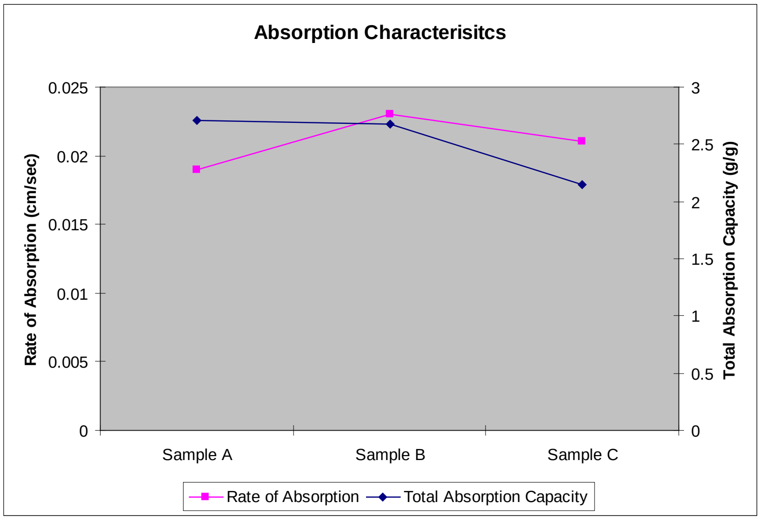

Fig 3.1 Absorption Characteristics

It is evident that the sample B i.e. ultrafine nonwoven with 135 GSM possesses both good rate of absorption and total absorption capacity. Higher absorption rate is due to the fact that sample B possesses more number of fibers per unit area, which in turn provides more capillary and eventually greater absorption rate compared to the knitted sample. Total absorption capacity is noticed higher in sample A when compared to sample B due to its higher areal density.

In case of the rate of absorption, the P value 0.007373 computed through ANOVA analysis revealed that there is a statistical significance between the sample means. Tuckey's post Hoc test resulted with the q values -4.23 , 1.64 and -2.58 for the interactions AB, BC and AC respectively, are less than the critical value 3.7 (at 95% confidence level), which proved that all the means difference is statistically significant.

The P value 1.35 x 10^{-07} showed that there is a statistical significance between the sample means. Tuckey's post Hoc test resulted with the q values 0.65, 11.48and 12.14 for the interactions AB, BC and AC respectively, which in turn proved that there is a significant difference between the ultrafine denier nonwoven samples and the difference between the nonwovens and knitted one is not significant.

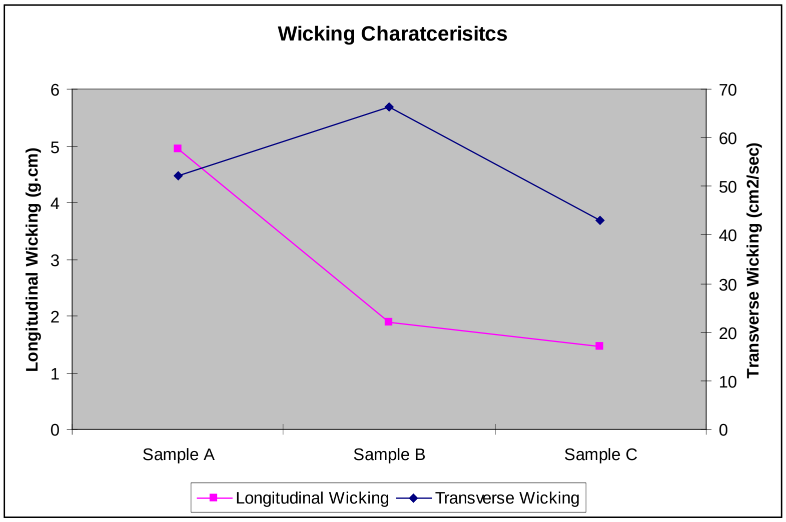

Fig 3.2 Wicking Characteristics

3.2 WICKING CHARACTERISTICS:

Wicking is the movement of liquid by capillary action. With regards to wicking against gravity, (longitudinal) sample A is superior to sample B and C, depicting a blotting paper. Wicking action was instantaneous and wicks uniformly across its surface. In the ultrafine, nonwoven fabric the surface area is large and the fine nature of the fibers resulted in smaller capillary pores on the fabric, which eventually produced greater capillary force. Sample A has more number of fibers per unit area and could have equipped with more number of capillaries and resulted with higher longitudinal wicking characteristics. The results coincide with the findings of Spencer – smith [2] and Umbhar K H [3]. It is seen from the fig. 3.2 that the sample B possess excellent wicking (traverse) across its surface.

P value from the above table ($4.72x10^{-12}$) confirmed the significant difference between the means. Further post HoC analysis produced the q values of 34.4, 4.7 and 39.1 for the interactions AB, BC and AC respectively, which confirmed the significant difference between the interactions.

Significant difference between the samples has been noticed through the P value 2.13 X 10^{-8}. The q values from post HoC test found were 12.4, 20.6, 8.1 for the interactions AB, BC and AC respectively recorded the significant difference between all the samples.

3.3 AIR AND WATER VAPOR PERMEABILITY:

Fig. 3.3 depicts the air permeability at 10 mm water head and the water vapor permeability of the three samples.

Sample C is highly permeable while sample A and B possesses reasonable air permeability. This may be attributed to random arrangement of fibers in a Nonwoven fabric whilst a knitted fabric whose structure is uniform, posses good permeability. Hence knitted fabric can breathe easily than its nonwoven counterpart because of the defined loop structure.

Water vapor or insensible perspiration can pass through openings between fibers and yarns in a breathable fabric. When water vapor is produced by the body, heat is removed giving a direct cooling effect. During exercise, both insensible and sensible perspiration are produced, but the latter increases in response to rising body temperature producing liquid at the surface of the skin. Fabrics used for active sportswear must have the ability to transport moisture away from the skin to the fabric surface for evaporation. The most effective fabrics will spread moisture over a wide area to maximize the surface area available for evaporation and hence cooling [4].

In the case of water vapor permeability the sample C can transmit more water vapor from the skin to the environment than the nonwoven fabrics. However, permeability of nonwoven fabrics is also above the normal level which indicates that it can offer breathability.

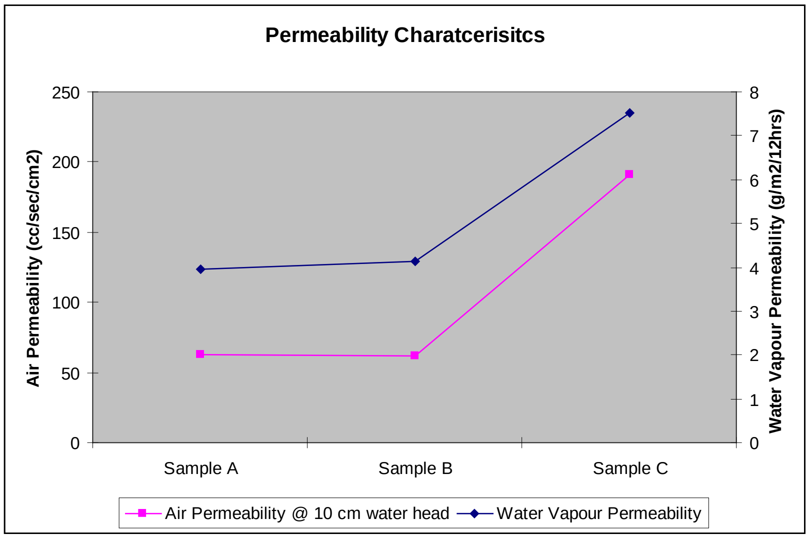

Fig. 3.3 Air and Water Vapor Permeability

The P value (1.49×10^{-17}) from ANOVA reported the statistically significant difference among the sample means. The post Hoc test confirmed that the difference between the samples A & B is not significant. (q = 0.18, 1.7.1, 106.9 for the interactions AB, BC and AC respectively)

From the analysis of variance, the statistical differences between the samples have been confirmed. The q values reported through post Hoc test (q = 0.91. 18.0, 18.1 for the interactions AB, BC and AC respectively) confirmed the insignificant difference between the two nonwoven samples A & B.

3.4 TENSILE STRENGTH & ELONGATION:

It could be noticed from the fig. 3.4 that the sample A possesses higher tensile strength and it derives it from the ultrafine denier fibers in its construction. The P value derived from ANOVA (7.2×10^{-21}) confirmed the significant difference between the samples. Further analysis revealed that (q = 12.8, 208.4 and 195.5 for the interactions AB, BC and AC respectively) all the mean differences are statistically significant.

Table 3.2 Subjective evaluation results

SUBJECTIVE EVALUATION						
PARTICULARS		Subject 1	Subject 2	Subject 3	Subject 4	**AVG**
Absorption Capacity	SAMPLE A	4	3	3	3	3.25
	SAMPLE B	3	3	4	4	3.5
	SAMPLE C	2	3	2	2	2.25
Dampness at the back	SAMPLE A	3	2	4	4	3.25
	SAMPLE B	3	3	3	4	3.25
	SAMPLE C	2	1	3	2	2
Air circulation	SAMPLE A	2	1	1	1	1.25
	SAMPLE B	1	2	3	2	2
	SAMPLE C	3	4	4	3	3.5
Sticky feel	SAMPLE A	4	4	4	3	3.75
	SAMPLE B	2	4	3	3	3
	SAMPLE C	2	1	2	1	1.5
Prickling feel	SAMPLE A	2	3	3	4	3
	SAMPLE B	3	3	4	4	3.5
	SAMPLE C	2	3	3	2	2.5
Garment stretch	SAMPLE A	2	1	2	3	2
	SAMPLE B	3	3	3	2	2.75
	SAMPLE C	4	3	4	4	3.75
Over all comfort	SAMPLE A	3	3	2	4	3
	SAMPLE B	3	4	3	4	3.5
	SAMPLE C	3	2	4	3	3

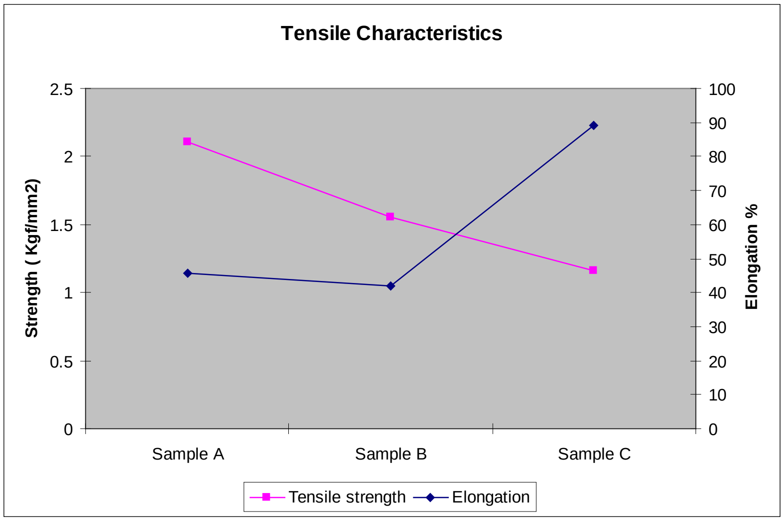

Fig. 3.4 Tensile Characteristics

The elongation is also found to be higher in the knitted sample C which owes to the loops in its structure, which is statistically confirmed from the variance analysis ($p = 4.57 \times 10^{-10}$). The q values from Tuckey's test were found to be 16.89, 11.95 and 28.8 for the interactions AB, BC and AC respectively, which signifies the difference among all the means.

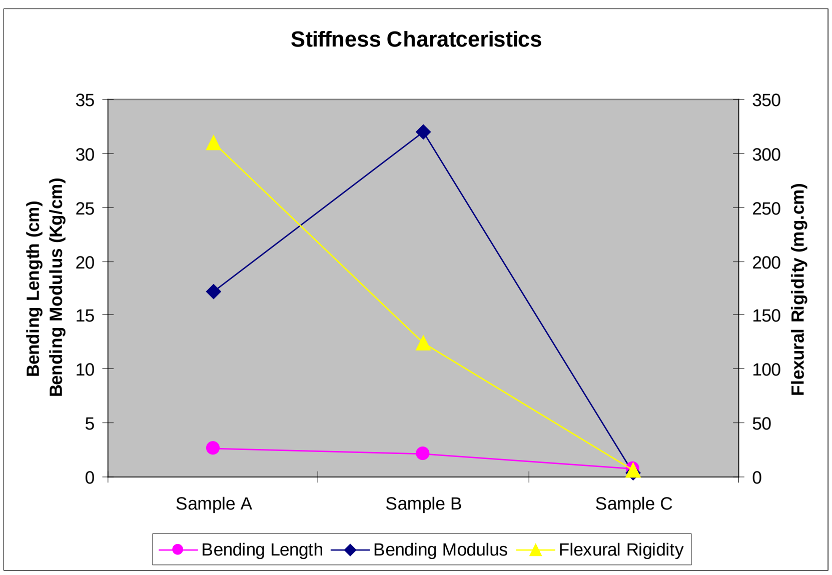

Fig 3.5 Stiffness Characteristics

3.5 STIFFNESS

The stiffness of the three samples were compared and presented in the fig.3.5.

The stiffness of a fabric in bending is very dependent on its thickness, the thicker the fabric, the stiffer it is, if all other factors remain the same.

Sample A is a stiff material compared to sample B and C, due to its higher areal density and thickness, while sample B possess moderate stiffness. Flexural rigidity is the ratio of small change in bending moment per unit width of the material to the corresponding small change in curvature. Increase in bending length will result in higher flexural rigidity, which is all depicted in the fig. 3.5.

The bending modulus is independent of the dimensions of the strip tested so that by analogy with solid materials it is a measure of 'intrinsic stiffness' [5]. This may be the reason behind the higher bending modulus for sample B than sample A even though it possesses lower thickness than sample A. Sample C is able to bend freely and can conform to various contours of body.
The P values computed through ANOVA (4.18E-13, 3E-18, 6.63E-19 for bending length, bending modulus and flexural rigidity respectively) confirmed the significant difference among the sample means.

The q values through Tuckey's test for the interaction between the samples A&B, B&C and A&C are 97.02, 61.93, 158.95 for flexural rigidity, 66.07, 141.17, 75.10 for bending modulus, and 13.35, 37.25, 50.60 for bending length respectively, revealed the significant difference among all the interactions.

3.6 SUBJECTIVE EVALUATION

To confirm the objective results, subjective evaluation was also conducted. Four national level basketball players were chosen as subjects and were explained well about the objective of the study. They were asked to wear both the knitted and ultrafine nonwoven garment and allowed to play the match. They were asked to give their opinion on a 4 - point rating scale about the various comfort related properties of the garment and are tabulated in the table 3.2.

From the above evaluation it is seen that the garment made out of ultrafine denier nonwoven extends better comfort and feel to the regular knitted one, coinciding with the objective results of wicking and absorption characteristics. It was accepted by all the players that the overall comfort is better in the ultrafine nonwoven sportswear.

4.0 CONCLUSION

The ultra-fine denier fiber nonwoven fabric compares favorably with knitted fabric which is used for sportswear manufacture. As per the study, from the selected samples, sample B i.e., ultra-fine denier fiber Nonwoven fabric of 130 GSM could be used for the replacement of knitted material due to its high wicking and absorption rate. However sample A i.e., ultra-fine denier fiber Nonwoven fabric of 170 GSM was also equivalent to 130 GSM fabric, but the stiffness values indicate that the fabric offers resistance to bending force. Selecting suitable aerial density of ultrafine denier nonwoven fabric is a key factor to conform to various contour of the body surface.

REFERENCES

1. Shishoo, R., Textiles in sport, The Textile Institute, Wood head Publishing Limited, Cambridge, England, P (1-3, 5)
2. Spencer – Smith, J.L., (1977). *The physical basis of clothing comfort, part 4: The passage of heat and water through damp clothing assemblies*, Cloth. Res. J. 5, 116
3. Umbach K., (1993) , *Moisture Transport & Wear Comfort in Micro fiber Fabrics*, Melliand Textilberichte, 74 174-176.
4. Slater K., (1977) *Comfort Properties of Textiles*, Textile Progress, vol. 9, No. 4, , 12-15
5. B P Saville (1999) Physical Testing of Textiles , Textile Institute, Wood Head Publishing Ltd., Cambridge, England