SWEAT-MANAGEMENT PROPERTIES OF SEMI BLEACHED-SOCKS USING DIFFERENT MAIN YARN AND PLATING YARN COMBINATIONS

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***Abstract:** The aim of the present work is to analyze the interaction of sweat with socks comprised of different main and plating yarn combinations. Main yarn selected of different blends Coolmax/cotton 50/50 (CC), 100% Coolmax (CM), 100% spun polyester (SP) and 100% micro spun polyester (MP) with linear density of 20 Nec (nominal english count) each. Plating yarns of two types i.e. nylon plated air covered (N_c) and polyester plated air covered (P_c) of linear densities 70 D and 75 D were used. The socks were prepared on a circular plain knitted machine with seven different yarn combination using main and plaiting yarns. Socks sample prepared abbreviated as CCN_c, CMP_c, CMN_c, SPP_c, SPN_c, MPP_c and MPN_c. Moisture management properties were measured MMT device. The liquid transport properties like wetting time, absorption rate, spreading speed, one way transportation capacity and overall moisture management capacity (OMMC) were measured and analyzed. The result shows that socks samples CCN_c containing hydrophilic materials like cotton so possess greater absorbency and least transportation of liquid. Socks samples especially CMP_c, MPP_c and SPP_c being hydrophobic materials exhibit 'good' moisture management properties.*

***Keywords:** Socks, main yarn, plating yarn, moisture management.*

1 INTRODUCTION

Clothing comfort has become one of the widest concerns for the textile manufacturers. Most of the end users like to be comfortable in their garments that may help them for better thermoregulation system and freedom of movement. Freedom of movement directly relates with construction and properties of knitted fabric made up of, while body temperature related to vapors and air circulation [1].

Many studies are there about construction and performance characteristics of fabrics and their assessment how the comfort properties and comfort levels can be imparted or achieved. Most of them emphasized over blends of conventional cellulosic materials like cotton, wool, regenerated materials i.e. rayon & bamboo and synthetic materials i.e. polyester & aramid fabric materials but not purely the synthetic materials along with core of polyurethane as elastomeric yarn. Out of already worked materials, 100% cotton and polyester is top of the list [2-12].

The reason of high consumption of cotton is its higher heat releasing and heat absorption properties accompanying moisture absorption and desorption respectively. This strengthens the buffering effect of the clothing between the human body and the surrounding environment. But the limitations regarding cotton based socks is its higher absorbency level which acquire poor moisture transportation and release properties consequently causes discomfort, less wearer performance, irritation, itching or prickling. They keep up the perspiration in the fabric layer next to the skin, giving wearer an uncomfortable feeling of wet and cold depending on the environment. The location of moisture inside the textile products influences the skin wetness as well as skin/textile friction. It has been observed that wet textile materials have high value of coefficient of friction causes smelling of socks and wearer foot deceases [13]. It has urged the researcher to develop such type of socks that possess better comfort properties.

Socks are the most widely used textile garment usually inside the shoes. More often these are used to attain comfort, better performance characteristics and to provide ease against rasping between foot and footwear. Socks are used to keep foot dry, cool and warm depending on the climatic conditions, body requirements and its activities. Dryness of foot plays vital role to keep foot free of perspiration and bacteria that cause variety of foot problems including blisters and athletic deceases. That why the wearer will feel comfort if we able to manage to transport sweat away from the skin surface, in the form of liquid or vapor consequently the fabric touching the skin feels cause dryness. The transport of both moisture vapor and liquid away from the body is called moisture management [13].

The most commonly used classes of knitting patterns consist of warp knitting and weft knitting. Another class of less rampant knit is called a circular knit. Warp knit is a type of knitting in which the yarns are stitched lengthways, in a zigzag pattern. The loops are interlocked in a lengthwise direction [14]. Due to its zigzag knitting across different columns, the knits are usually done by machine. While weft knit is a type of knitting in which yarns are stitched width-wise, across the fabric. Some examples of weft knits are plain knits or rib knits [15]. The third class of knits that is relevant to this project is circular knit. These knits can produce tube forms that are seamless [16], since most knitted garments are in tube forms such as arm sleeves or socks. Similarly to weft knits, circular knits can be done either hand-made or by machine.

After all it is decided to compare comfort properties most likely to be moisture management of socks made up of synthetic materials along with different blended materials.

Moisture management in socks essentially refers to how well material is transporting moisture out and keeping the wearer dry. The moisture remaining in the socks can further increase body temperature leading to more perspiration. The ultimate objective of managing moisture in socks is to ensure moisture is transported to the outer surface in the shortest possible time. Once transporting outwards, the moisture should spread to a large surface area and evaporate as fast as possible with the wearer experiencing a feeling of dryness [17]. Moisture management has the following functions: regulation of body temperature – when core temperature of human body exceeds 37°C, it starts to sweat generation. Transporting the sweat away from the skin and evaporating it to the atmosphere, reduces body temperature [18].

Above mentioned problem of sweat poor transportation and release from the core of fabric structure has urged the researcher to develop such type of socks that possess best liquid management characteristics. The significance of this research is to provide comfort against perspiration produced inside our socks and its evaporation that may keep wearer skin dry. The moisture absorption and its transfer within the socks play an important role for evaluation of wearer comfort and performance of textile product against wetness, sweat and skin/textile friction.

The main objective of this study was to compare sweat management properties regarding liquid moisture management of socks made up of synthetic materials comprised of different blend on overall moisture management capacity of socks.

To measure moisture management properties of sportswear and dynamic liquid moisture properties, moisture management tester (MMT) was established. This tester is very unique in its construction and fulfills all the aspects of sweat management introduced here as different indices for fabric top and bottom sides [18].

The liquid management trend in the form of 'wetting time', 'absorption rate', 'one-way transport capability', 'spreading/drying rate' and 'overall moisture management capacity' (OMMC) were measured and then analysed. Wetting time is actually the ability of fabric to wet and is defined as the time [s] when the fabric happening to be wetted as test is started. 'Absorption rate' is the speed at which the mean quantity of generated sweat is absorbed during the initial change of water content. 'Spreading speed' is the accumulated rate of surface wetness to a maximum radius from the point at which the drop is fall. The 'maximum wetted radius' is the greatest water ring radius measured on the surface of fabric. 'Accumulative one-way transport capability' is the difference between the areas of the liquid moisture content curves of a fabric with respect to time [5]. 'Overall (liquid) moisture management capability' (OMMC) is an index is an intimation to instruct the overall ability of the fabric to manage the transport of liquid moisture and calculated using equation:

$$OWTC = C_1MAR_b + C_2OWTC + C_3SS_b \quad (1)$$

where C_1, C_2, and C_3 are the weights of the indexes of the absorption rate.

2 MATERIALS AND METHODS

2.1 Yarns (type and properties)

Yarns of two types, main and plating, were deployed together side by side to prepare footy socks. Main yarn used is in direct contact with the skin and provides desired comfort while plating yarn, characterized by limited elasticity, provides lateral force to conjoin main yarn with the skin and clasp the socks avoiding slippage.

Main yarns of four types i.e. Coolmax/cotton 50/50 (CC), Coolmax 100% (CM), spun polyester 100% (SP) and micro spun polyester 100% (MP) of alike fineness (20/1 Ne) were used. While plating yarns (fixed linear densities & draft ratio of elastane) were of two types 1) nylon air covered elastane (N_C), 2) polyester air covered elastane (P_C) as shown in Figure 1.

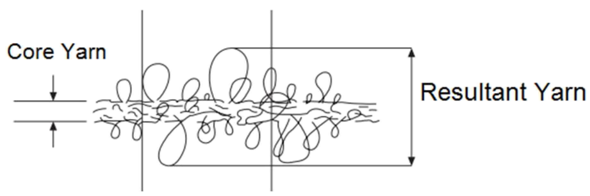

Figure 1 Side view of ACV yarn - resultant and elastane yarn [19]

Table 1 Main yarn testing results

Sr. No	Parameters	Standard test method/ Equipment	Main yarn 20/1 carded			
			*CM	*CC	*SP	*MP
1	Linear density [N_{ec}]	ASTM D1907	20.58	20.24	20.10	20.38
2	Turns/inch**	ASTM D1422	15.99	17.05	12.95	13.87
3	Tenacity [cN/tex]	ASTM D2256	16.09	14.07	30.02	33.83
4	Uniformity percentage [%]	USTER 5	9.42	8.97	8.97	87.22
5	Hairiness		7.14	6.15	5.77	8.78

**turns per inch means the number of twists per inches of main yarn *CM= Coolmax; *CC= Coolmax/cotton 50/50; *SP= spun polyester and *MP= micro polyester

Table 2 Plating yarn specifications

Sr. No	Sample ID	Yarn Description	Composition [%]	
			polyester/nylon	elastane
1	P_c	20D-75/36/1 D 100% polyester air covered elastane yarn (95/5)%	95.22	4.78
2	N_c	20D- 70/24/1 D 100% nylon air covered elastane yarn (95/5)%	95.52	4.48

Testing results of main and plating yarns (Tables 1 and 2) were measured under standard atmospheric conditions 21±1°C and 65±2% RH (ASTM- D1776).

2.2 Socks manufacturing

Total 7 socks samples were developed using different yarn combinations (CCN_c, CMP_c, CMN_c, SPP_c, SPN_c, MPP_c and MPN_c) on socks knitting machine of specifications (Lonati FL-454J, model 2004, gauge 12GG, diameter 4″, speed 250 rpm, feeders 2 and number of needles 144) as shown in Figure 2.

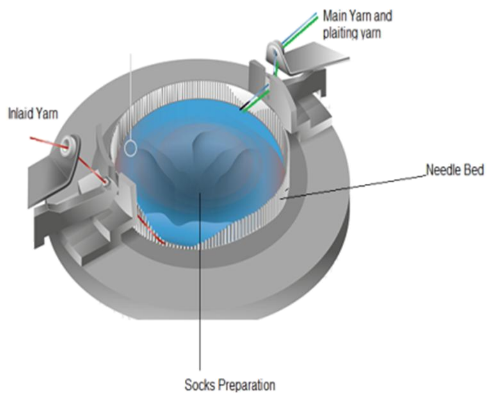

Figure 2 Internal view of knitting machine [20]

The selections of materials were done on the basis of their availability for development of socks samples.

All of the developed socks samples exhibit the same single jersey plain fabric structure as shown in Figure 3.

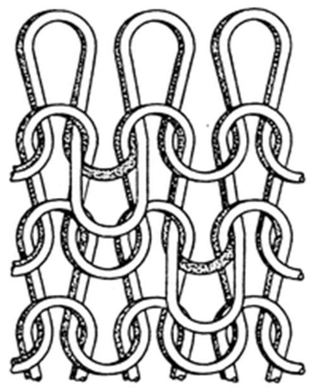

Figure 3 Structural of plaited socks sample [21]

Socks samples physical and composition results after half bleaching are given in Tables 3 and 4 using standard test method AATCC 20A.

Table 3 Physical testing of socks

Sr. No	Sample	Socks weight [GSM]	Body stretch [%]	Thickness [mm]	Tear strength [N]	Extension [mm]
1	CCN_c	331.64	21.88	1.52	306	135
2	MPP_c	332.3	20.5	1.52	437	112
3	MPN_c	331.5	20.25	1.38	398	133
4	CMP_c	332.9	21	1.54	369	125
5	CMN_c	331.75	21.56	1.38	299	137
6	SPP_c	332.3	21	1.5	376	109
7	SPN_c	332.5	20.94	1.6	406	139

Table 4 Quantitative fibre analysis of socks

Sr. No	Sample	Sample description (plating yarn + main yarn)	Composition [%]	Quantitative analysis [%]
1	CCN_c	20D Lycra (5%)-70/24/1 PA 95% + 20/1 Coolmax/cotton 50/50	PET/cotton/PA/Lycra	35.73+37.54+21.86+4.87
2	MPP_c	20D Lycra (5%)-75/36/1 PET 95% + 20/1 micro spun polyester 100%	PET/Lycra	95.09+4.91
3	MPN_c	20D Lycra (5%)-70/24/1 PA 95% + 20/1 micro spun polyester 100%	PET/PA/Lycra	74.45+21.29+4.26
4	CMP_c	20D Lycra (5%)-75/36/1 PET 95% + 20/1 Coolmax 100%	PET/Lycra	95.16+4.84
5	CMN_c	20D Lycra (5%)-70/24/1 PA 95% + 20/1 Coolmax 100%	PET/PA/Lycra	74.2+21.31+4.49
6	SPP_c	20D Lycra (5%)-75/36/1 PET 95% + 20/1 spun polyester 100%	PET/Lycra	95.44+4.56
7	SPN_c	20D Lycra (5%)-70/24/1 PA 95% + 20/1 spun polyester 100%	PET/PA/Lycra	74.57+21.05+4.38

3 RESULTS AND DISCUSSION

Developed socks samples were evaluated for their interaction to sweat generation using MMT tester.

3.1 Top and bottom fabric wetting time

Figure 4 demonstrating wetting time top (WT_{tp}) and bottom (WT_{bm}) of all socks sample. WT_{tp} and WT_{bm} is actually the time start to wet socks samples [5-9].

Figure 4 portrays that socks sample CCN_c exhibit highest values of wetting time than rest of six combinations of socks samples due to presence of cotton contents. Cotton fiber being hydrophilic retains the sweat for maximum time due to higher adhesion forces between sweat and fiber surface. This inherited behavior exhibit poor moisture release and transport consequently swells fiber reduces interspaces between fibers and yarns inside the sock structure.

Figure 4 also portrays least spending time samples CMP_c followed by MPNc, SPPc, MPP_c, CMN_c and SPN_c present swift flow of generated sweat through its structure.

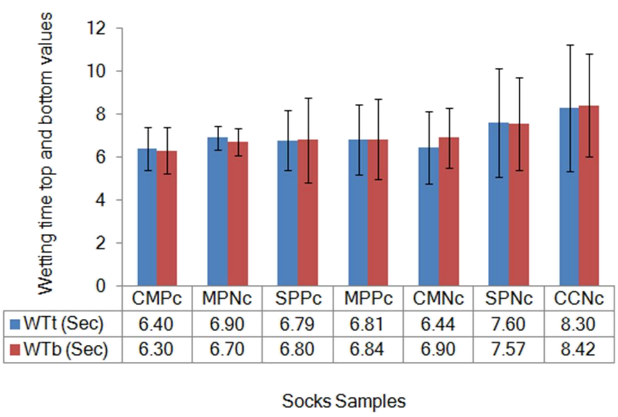

Figure 4 Mean comparison of wetting time top and bottom

As studies proved that wetting of the fabric corresponds fiber-air interface replaced by fiber-liquid sweat interface [19]. In this case, air spaces present context to extensibility values (139 mm and 137 mm) present inside socks structure entrapped the sweat contents exhibiting higher time to air voids and hydrophilicity of materials that enhance force of adhesion between fiber surface and water molecules` wettability to spend less time to absorb sweat. Another parameter TPI (turns per inches) in CM 100% is lower than MP 100% followed by SP 100% enhances the capacity to hold higher amount of sweat than MP 100% and SP 100% due to presence of air voids within the yarn structure between fibers [20].

3.2 Mean comparison of top and bottom absorption rate

Figure 5 reveals that socks sample CCN_c exhibit highest rate of absorption at top (AR_t) and bottom (AR_b) which is due to presence of cotton contents (highest regain). Out of rest 6 socks samples (synthetic material) react to sweat with varying rate of absorption at bottom side (skin side) can be ordered, MPN_c > MPP_c, SPN_c > SPP_c, CMP_c > CMN_c.

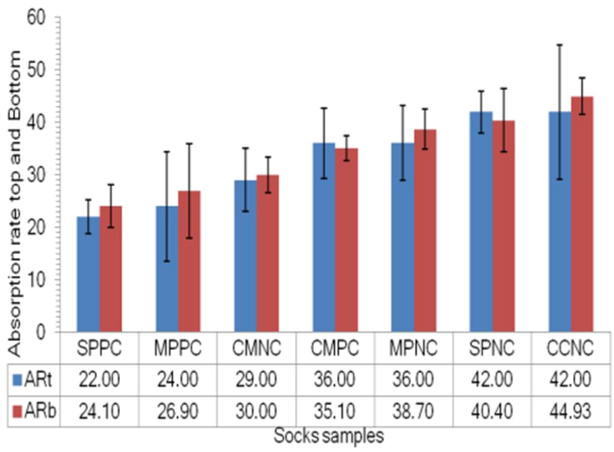

Figure 5 Mean comparison of absorption rate at top and bottom

Socks samples MPN_c and SPN_c (nylon plated) exhibit higher rate of absorption than MPP_c and SPP_c (polyester plated) because of higher nylon regain than polyester fiber. The reason of higher AR_b of nylon plated socks is also due to higher values of extension [mm] which portray the presence of dominant air voids than polyester plated socks.

Socks samples CMN_c and CMP_c have interacted the sweat in very different way. The AR_b in socks samples with plated polyester is higher than nylon plated socks. The reason is presence of cross sectional multi-channels enhance the rate of transportation of sweat water. Polyester plated socks sample (CMP_c) have also the thickness more than CMN_c so AR_b of the synthetic socks samples have the order MPN_c > MPP_c and SPN_c > CMP_c. Reason of higher AR_b in MPN_c than MPP_c is due higher value of extension [mm] indicates the presence of maximum air voids that hold maximum concentration of generated sweat. While SPN_c > CMP_c socks samples, it is due to presence of maximum air voids, higher thickness of fabric, higher values of imperfection and lower twist per meter values than CMP_c.

3.3 Mean comparison of spreading speed at top and bottom

In Figure 6, it is observed that socks sample CMP_c shows highest spreading speed followed by MPP_c, SPP_c CMN_c, MPN_c, SPN_c and CCN_c respectively. 'Spreading speed' is the accumulated rate of surface wetting from the center of the specimen where the test solution is dropped up to the maximum wetted radius [5, 9].

Per Figure 6 if we compared the spreading speed values of socks sample having similar main yarns of same specifications and different plating yarns (polyester and nylon), revealed that the socks samples CMP_c, MPP_c and SPP_c (polyester plated) shown greater spreading speed values at bottom side (SSb, contact with skin) than socks samples containing nylon plated yarns but trend is different in socks samples due to presence of cotton contents.

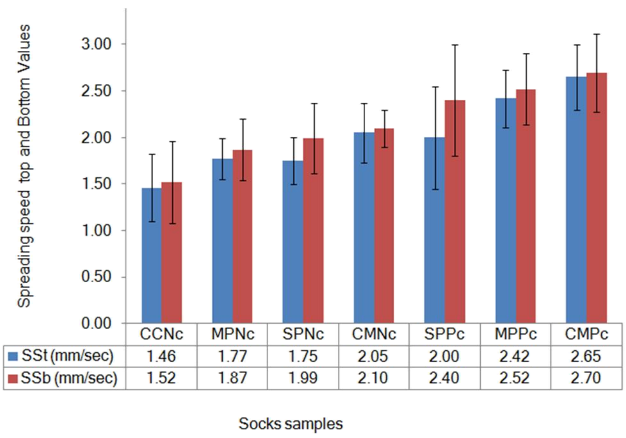

Figure 6 Mean comparison of spreading speed

Socks samples with highest spreading speed values at skin contacting side were evaluated and it was found that in socks sample CCN_c contains 38% cotton and 36% polyester (1:1). This sample exhibit the minimum value of the spreading speed at top and bottom sides of its fabric surface compared to rest of 6 different combinations of socks samples. It is all due to presence of cotton contents lead to absorb more water clinginess to the surface of cotton fiber and later its penetration to micro pores due to more of its amorphous region compared o manmade fibers.

On the other hand, socks sample SPP_c showed the greater value of spreading speed (SSb) than SPN_c at bottom side. Higher value of spreading speed at bottom (SSb) is due to higher polyester contents about 75% in SPPC than SPNC (75%), less fabric thickness and compactness than nylon plated socks samples (SPN_c).

3.4 Mean comparison of accumulative one-way transport index (AOWTI) and overall moisture management capacity (OMMC) of socks samples

Figure 7 representing AOWTI [%] and OMMC results of socks samples. OMMC is grading assigned to socks samples as 'excellent', 'good' or 'poor' in sweat management performance. Grading scale range is given in Table 5.

Table 5 Grading of moisture management indices tester [7]

Index	Grade				
	1	2	3	4	5
AOWTI	<-50	-50-99	100-199	200-400	>400
[%]	poor	fair	good	very good	excellent
OMMC	0.0-0.19	0.20-0.39	0.40-0.59	0.60-0.80	>0.80

Figure 7 interprets the performance of socks samples and portrays similar trend between OMMC and AOWTI. Excellent results against AOWTI and OMMC values are attained by socks samples can be ordered CMP_c followed by MPP_c, SPP_c, CMN_c, MPN_c, SPN_c and CCNc respectively.

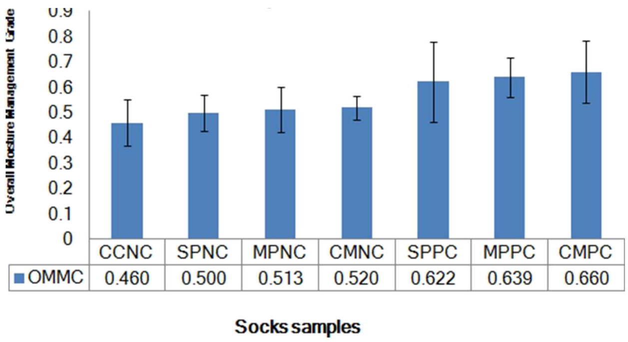

Figure 7 Mean comparison of OMMC values

Further, if we compare AOTI and overall moisture management capacity of socks samples context to plating yarn used inside the socks, the best results for OMMC and AOWTI are of Coolmax polyester (CMP_c) are good as compared to Coolmax nylon covered (CMN_c) while micro-polyester polyester covered (MPP_c) exhibit better moisture management characteristics compared to micro-polyester nylon covered (MPN_c), similarly spun polyester -polyester covered (SPP_c) exhibit better overall moisture management properties compared to spun polyester nylon covered and Coolmax cotton nylon covered exhibit least (poor) moisture management properties. This trend is due to higher content of polyester fiber being hydrophobic in nature suck away the sweat to fabric outer surface and due to higher values of extensibility values of socks samples. These higher values portray the presence of majority of free spaces within the socks structure consequently increasing its higher OMMC of values (Table 3).

OMMC and AOWTI values of developed socks were analyzed statistically using one way variance analysis and found that there is significant effect of TPI (p value is 0.046) and extension value (p value is 0.018). Main effect plot between OMMC, AOWTI, TPI and extension value [mm] are given in Figure 8.

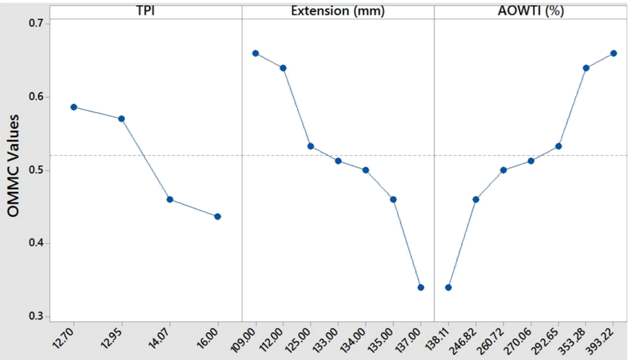

Figure 8 Main effect plot between TPI vs extension [mm] and AOWTI [%]

Unable to attain OMMC rating as 'excellent' samples were first processed and allow them to be relaxed to retain strain energy due to different tensions in spinning and knitting. This chemical treatment of socks has affected the fabric density due to contraction consequently reducing air void and moisture accumulation capacity in socks.

Das B., et al. [10] mentioned in his work that sweat peeing through socks samples involves the two processes which are diffusion and sorption-desorption. Water vapor diffuses through socks samples involves openness within the yarn as well as free voids inside the fabric correspond to inter-fiber interstices in yarn along fiber itself while moisture transport through sorption-desorption process will increase with the hygroscopicity of the material [10].

4 CONCLUSION

In this research we have mainly emphasized over moisture management properties of plated socks samples produced by using different type of four main yarns and two plated yarns with total 7 combinations (CMPc, CMNc, MPPc, MPNc, SPPC, SPNc and CCN_c). All of the combinations were analyzed for their overall moisture management performance and found that best socks samples combination were CMP_c, MPP_c and SPP_c. According to the results we concluded that including yarn and socks parameters i.e. TPI and extension [mm] significantly influence overall moisture management and accumulative one-way transport index values of plated socks samples and samples CMP_c, MPP_c and SPP_c are rated as 'good' in moisture interaction.

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