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Research Article

Examining absorbency properties of the pile loop knitted fabrics with moisture management tester

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ABSTRACT

Pile loop knitted fabrics including the form-fitting properties of single jersey are much popular and generally used in clothing such as leisurewear, sportswear, sock etc. though they are terry fabric and the using with the aim of drying expectation. In this study, water absorption properties of pile loop knitted fabrics were investigated in a moisture management tester. For this purpose, twelve pile loop knitted fabrics were obtained by using 100% carded cotton ring spun yarns with Ne 30, Ne 24 yarn numbers as pile yarn, and 100% polyester filament yarn with 70 denier and 90 denier as ground yarn at three different sinker heights which are 2.2 mm, 2.5 mm and 2.8 mm. After knitting, pile loop knit fabrics were dyed in the same processes including scouring, dying, and washing processes. Physical properties of the fabrics were measured according to relevant standards. As for absorption properties of the fabrics were determined according to AATCC 195 standard in SDL Atlas Moisture Management Tester. The study revealed that bottom absorption rate and spreading speed is higher than top absorption rate and spreading speed for all pile loop knitted fabrics. The pile loop knitted fabrics having higher pile show slightly better absorption rate in comparison the pile loop knitted fabrics having lower pile. For different pile heights, top absorption rate is less influenced by pile yarn count whereas bottom absorption rate much affected. Liquid transport capability (OWTC) of the pile loop knitted fabrics containing coarse pile yarn in low sinker height is better, whereas it is better in the fabrics containing fine pile yarn in high sinker height. Moisture management performance (OMMC) is higher in the fabrics having low sinker height, fine ground and pile yarn.

1. Introduction

Knitted terry fabrics are produced that ground yarn and pile yarn are fed to needles in the knitting area according to pile loop knitting technique. They have a wide range of usage from clothing to home textiles. The usage for clothing requires that these fabrics have particularly good moisture and thermal comfort properties. The comfort properties of the fabrics can be measured thanks to the developed devices such as MMT, Alambeta, and hot-plate.

The elongated pile loops are plated on the normal-length ground loops on the technical face of the fabric. The pile loops show as a pile between the wales on the technical back of the fabric (Figure 1) [1].

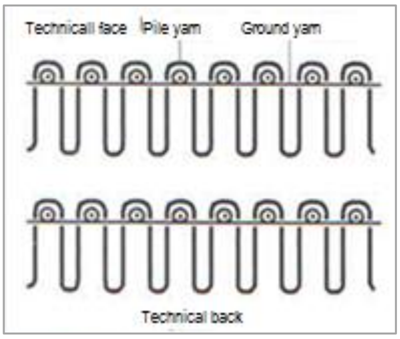

Figure 1. Needle diagram of pile loop knitted fabric

The pile of knitted terry fabric is made by sinkers whose nibs are larger than standard sinkers (Figure 2). This nib is protruding in the pile loop sinkers whereas it is flat in standard sinker [1].

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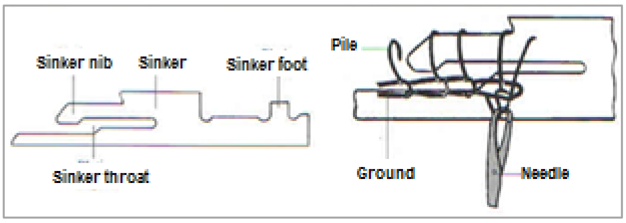

Figure 2. Pile loop sinker

In knitting terry machines, the pile yarn is laid on the pile sinker (Figure 3). Here, the yarn held by the nib of the sinker is pulled by the needle on both sides of the sinker to form the bow. This bow structure is seen as a pile on the fabric [1].

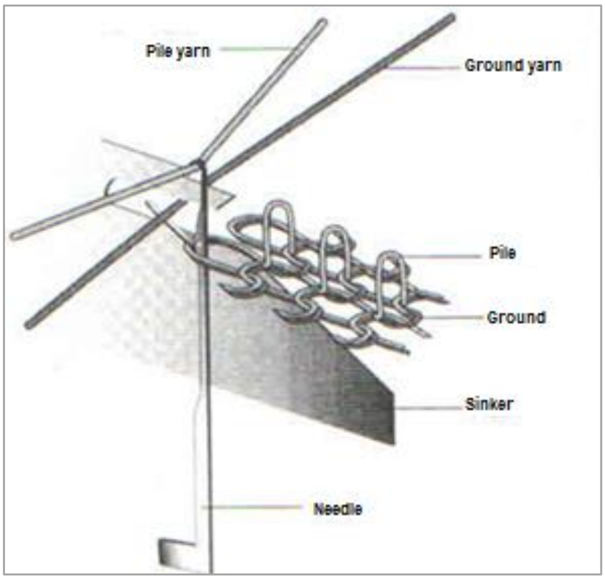

Figure 3. The formation of pile loop

The transfer of fluid with the absorption of moisture or liquid is an important feature in the comfort of the garments. Liquid absorbency depends on the type of fiber raw material and is affected by the hydrophilic or hydrophobic character of the fiber. Hydrophobic fibers (usually synthetic fibers) that have little or non-affinity to the water molecule exhibit little or no fluid absorption while hydrophilic fibers (natural and regenerated fibers, etc.) are attracted to the water molecule exhibiting high fluid absorption. The transfer of liquid in the garments is mainly influenced by the liquid absorption due to the type of raw material, capillarity of the fibers and yarns, the yarn production method, the surface forming technique, the fabric structural parameters and the finishing process applied to the fabric.

The removal of the moisture from the human body in vapor and liquid form is defined as moisture management of a fabric. In SDL Atlas MMT (Moisture Management Tester) (Figure 4), the dynamic fluid or moisture management properties of the fabrics in three dimensions can be measured. The electrical resistances of textile materials are very high. Resistance decreases when they are wet or moist [4]. MMT tester operates on the principle that the contact electrical resistance changes with the liquid presence of the fabric, and the amount of liquid in the fabric is determined from the difference between the voltages on the circuit [5].

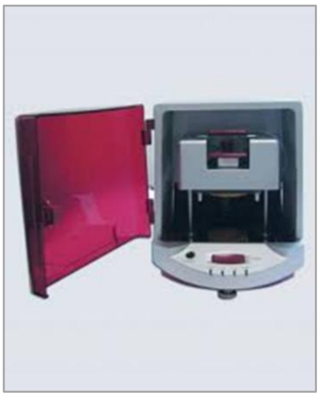

Figure 4. MMT tester (SDL Atlas)

In MMT, the measurement sensors measure the resistance difference (Figure 5). The device contains coaxial circle profiled humidity sensors where the fabric is placed in contact with and tested. The amount of test solution defined in the method and standards is left on the top surface of the fabric by the device during the first 20 second period of the 2 minute test period. MMT detects and measures the transfer behavior of the test solution transferred in three directions in the fabric [6].

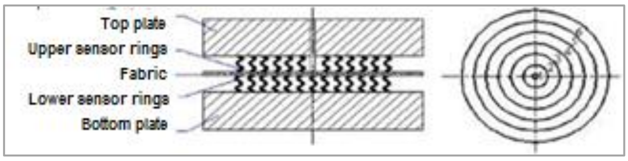

Figure 5. The measurement sensors and rings in MMT

The amount of liquid moisture in the fabric has a characteristic that is expressed parabolically with the drip of the liquid cloth, expressed by the curves U1 and U2 and parabolically decreasing with the liquid absorption of the fabric (Figure 6) [6].

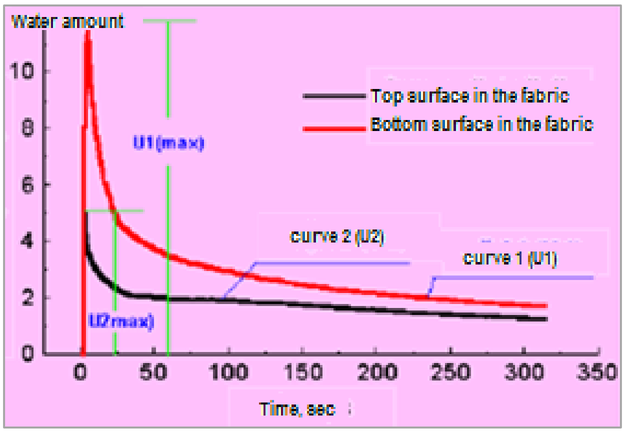

Figure 6. Changing of water amount on fabric surfaces [6]

One way transport capability (OWTC) is the difference in the amount of cumulative liquid (moisture) between the two surfaces of the fabric [7] and is one of the factors affecting the level of drying of the fabric. The calculation of OWTC is given in Equation 1.

OWTC = (Area (U1) - Area (U2)) / Test duration (1)

U1: Water amount in fabric bottom surface

U2: Water amount in fabric top surface

OWTC values with minus signs indicates that the U2 curve area is larger than the U1 curve area, that is, the transmission of liquid moisture from the fabric top surface to the bottom surface is weak [6].

OMMC (overall moisture management capacity) is an index that determines the total transfer capacity of the liquid in the fabric [7]. The calculation of OMMC is given in Equation 2.

OMMC = C1 * BAR + C2 * OWTC + C3 * BSS (2)

Bottom absorption rate: **BAR**

One way transport capability: **OWTC**

Bottom spreading speed: **BSS**

Coefficients values; C1= C3 = 0.25 and C2 = 0.5

The good value of OMMC indicates that the liquid is effectively transferred from top surface to bottom surface, that the rate of absorption of the liquid transferred to bottom surface is higher and spreads rapidly. MMT scale values are given in Table 1.

Table 1. MMT scale values [8]

Index		**Scales**				
		1	**2**	**3**	**4**	**5**
Wetting time (sec)	**Top**	≥120 no wetting	20-119 slow	5-19 moderate	3-5 rapid	<3 very rapid
	Bottom	≥120 no wetting	20-119 slow	5-19 moderate	3-5 rapid	<3 very rapid
Absorption rate (%/sec)	**Top**	0-9 very slow	10-29 slow	30-49 moderate	50-100 rapid	>100 very rapid
	Bottom	0-9 very slow	10-29 slow	30-49 moderate	50-100 rapid	>100 very rapid
Max wetted radius (mm)	**Top**	0-7 no wetting	8-12 small	13-17 moderate	18-22 rapid	>22 very rapid
	Bottom	0-7 no wetting	8-12 small	13-17 moderate	18-22 rapid	>22 very rapid
Spreading speed (mm/sec)	**Top**	0,0-0,9 no wetting	1,0-1,9 slow	2,0-2,9 moderate	3,0-4,0 rapid	>4,0 very rapid
	Bottom	0,0-0,9 no wetting	1,0-1,9 slow	2,0-2,9 moderate	3,0-4,0 rapid	>4,0 very rapid
OWTC (%)		<-50 very bad	-50-99 bad	100-199 good	200-400 very good	>400 excellent
OMMC		0,0-0,19 very bad	0,2-0,39 bad	0,4-0,59 good	0,6-0,8 very good	>0,8 excellent

The fabrics are defined below according to MMT scale values [8]:

- Waterproof fabrics
- Water-repellent fabrics
- Slow absorbing and slow drying fabrics
- Rapid absorbing and slow drying fabrics
- Rapid absorbing and rapid drying fabrics
- Water permeable fabrics
- Moisture-sensitive fabric (moderate/rapid absorbing and wetting, rapid dispersion on the surface, spreading and wide spreading area, good/excellent OWTC)

The previous works related to the subject are briefly summarized below.

Chattopadhyay and Chauhan [9] found that the height of the capillary wetting for ring yarns is higher than that of compact yarns, and also coarse yarns have a higher capillary wetting than thin yarns.

Chen et al. [10] researched that the liquid absorption properties of textile materials and one way transport capacities on double layered knitted structures. They indicated that the multi-layer knitted structures exhibit faster absorption and liquid setting properties than the conventional structure.

Prahsarn [11] determined that the fabric liquid absorption capacity is largely dependent on the fabric thickness, than the properties of the blended fibers, and also the fabric thickness, yarn count and fabric tightness are influential on the absorption capacity.

Jiao et al. [12] investigated that thermal and mechanic comfort properties of the clothes made of hydrophilic polyester and hydrophobic polyester fabrics. They found that capillary wetting and liquid moisture transmission properties of hydrophilic polyester fabrics have an effect on breathability perception.

Karahan and Eren [13] examined the static liquid absorption properties of towel fabrics produced at different weft and warp setts, different yarn properties and pile heights. They indicated that the towel fabric produced with the two-plied ring carded yarn has higher liquid absorption values than that of the fabric produced rotor yarn. They also found that the increase in weft and warp setts results in a decrease in liquid absorption, and an increase in pile height causes increase liquid absorption.

Kim et al. [14] investigated that different woven and knitted fabrics having high liquid absorption capacity and found that the values of tightness and fiber size are minimum, and the values of thickness and pore size are maximum in the fabrics for optimum absorption behavior.

Long and Hai-Ru [15] show that the liquid transfer is dependent on the absorption properties of the fibers on both faces of the fabric and the difference between these properties.

Özdil et al. [16] researched that the moisture management properties of the knitted fabrics having different cotton yarn counts different twist values. They determined dynamic liquid transport properties of the fabrics with SDL-ATLAS Moisture Management Tester. They revealed that the effects of yarn count and yarn twist coefficient on the moisture management properties were significant, and all the fabrics used in the study have good moisture management capability.

Özkan and Kaplangiray [7] examined that moisture management properties of different blends of wool/polyester fabrics which are used in winter military clothes with MMT test device. They indicated that the moisture management properties improved when the wool fiber diameter decreased and as the percentage of fiber increased, and the overall moisture management value decreased as the yarn count increased and the percentage of polyester fiber increased.

Uyanik [17] determined the liquid moisture management properties of vortex knitted fabrics. For this purpose, the vortex yarns with 19,7 tex obtained different blend ratios by using carded cotton, viscose, modal, silver added polyester (Flexsil-D2^{TM}), polyester, and nylon 6.6 fibers were knitted in two different stitch lengths as tight and loose, and dyed considering fiber types. The results of the study revealed that moisture management properties of vortex knitted fabrics are much affected by fiber types in comparison with fabric tightness. Modal and nylon fibers are very positive in terms of moisture management performance. The vortex yarns having low diameter, high shape values that is more rounded, and high density improve moisture management performance of the knitted fabrics whereas the hairy yarns and higher fabric thickness reduce it.

Wallenberger [18] determined that the most advantageous fiber in terms of comfort is quickly transfer the liquid and dry it in a short time, and a fiber with higher liquid absorption capacity causes wet feeling and comfortless due to the long drying time.

Yüksel and Okur [8] investigated that the relationships between subjective comfort evaluations and fabric characteristics that can be measured objectively, and to evaluate properties associated with comfort of fabrics having different material and structural features. They found that there was a significant correlation between top absorption rate and wetting time measured in MMT and the wet feelings of the subjects.

As seen in the previous works, although there have been some studies in the literature to determine the moisture performance with MMT tester or other devices, no study has been done on the use of knitted terry fabrics. Therefore, it is aimed to present absorbency and other liquid (moisture) performance characteristics of the knitted terry fabrics which are common in garment use in this study with MMT tester.

2. Material and Method

In this study, twelve samples of three different platinum heights as 2.2 mm, 2.5 mm, and 2.8 mm were obtained by using Ne 30 and Ne 24 100% cotton yarns as pile yarns, 70 denier and 90 denier 100% polyester filament yarns as the ground yarn to investigate the moisture management properties of the knitted terry fabrics. Knitted terry fabrics are dyed with the same processes including scouring, dyeing and washing. The physical properties of the fabrics are determined according to the standards TS EN ISO 14971, TS 629, TS EN 12127, and TS 7128 EN ISO 5084, respectively, and the absorption properties are determined with SDL Atlas Moisture Management Tester according to AATCC 195 standard. All measurements and tests were performed under standard atmospheric conditions, and repeated as five times. The production parameters, pile yarn properties measured by Uster Tester 5 device, and fabric properties are given in the Tables 2, 3 and 4, respectively.

Table 2. Production parameters

Ground yarn	70 Td - 90 Td polyester
Pile yarn	Ne 24 – Ne 30 100% cotton
Sinker heights	2.2 mm - 2.5 mm - 2.8 mm
Knitting machine	30 inch, E 20, 44 feeders, Keumyong KM-3SV

Table 3. Pile yarn properties

Yarns	Ne 30	Ne 24
USTER, %	12.1	11.3
Thin -50%	13	2
Thick +50%	182	107
Neps +200%	251	91
Hairiness, H	7.1	7.7
Tenacity, cN/tex	15.4	18.3
Elongation, %	4.6	5.0
Twist (T/m)	820	733

Table 4. Knitted terry fabric properties

Yarn number		Sinker height (mm)	Stitches/cm		Weight (g/m²)	Thickness (mm)
Ground (Td)	Pile (Ne)		Courses	Wales		
90	30	2.2	12.5	9	214.35	1.58
90	30	2.5	12.5	9	230.87	1.85
90	30	2.8	14	10	259.76	1.94
90	24	2.2	12.5	9	268.48	1.85
90	24	2.5	14	9	286.57	1.88
90	24	2.8	15.5	9.5	331.50	2.16
70	30	2.2	12	9	192.67	1.50
70	30	2.5	13	10	236.73	1.85
70	30	2.8	14	9.5	242.99	1.75
70	24	2.2	12.5	9	240.05	1.69
70	24	2.5	12.5	9	264.33	1.82
70	24	2.8	14.5	10	320.24	2.01

Additionally, the regression tests were made in 0.05 significance level for statistical analysis. The results were given in Table 6.

3. Results and Discussion

The moisture management properties of knitted terry fabrics are given in Table 5.

Table 5. MMT test results of knitted terry fabrics

Ground (Td)	Pile (Ne)	Sinker height (mm)	Wetting time (sec)		Absorption rate (%/sec)		Spreading speed (mm/sec)		OWTC (%)
			Top	Bottom	Top	Bottom	Top	Bottom	
90	30	2.2	50.76	11.87	19.25	52.44	0.11	0.45	639.86
70	30	2.2	34.36	12.31	32.46	46.04	0.20	0.48	310.61
90	24	2.2	52.72	17.18	11.92	23.94	0.32	1.04	741.83
70	24	2.2	20.36	13.97	46.46	14.55	0.27	0.46	387.72
90	30	2.5	31.20	10.18	25.98	39.88	0.28	0.57	403.74
70	30	2.5	61.22	14.31	18.66	83.10	0.08	0.34	641.73
90	24	2.5	47.57	14.31	25.83	47.40	0.13	0.35	629.66
70	24	2.5	41.57	8.76	16.33	20.97	0.17	0.89	751.02
90	30	2.8	61.89	15.38	19.91	54.80	0.08	0.32	726.26
70	30	2.8	57.30	15.47	23.08	50.05	0.12	0.34	685.95
90	24	2.8	43.27	13.57	27.21	37.44	0.15	0.39	605.31
70	24	2.8	42.88	12.60	26.32	34.79	0.13	0.43	591.71

Test results were examined in the subheadings of absorption rate (AR), spreading speed (SS), one way transport capability (OWTC) and moisture management (OMMC) performance.

3.1. Absorption Rate (AR)

The graph of absorption rates of knit towel samples is given in Figure 7. According to graph, the bottom AR are higher than that of the top except sample having 2.2 sinker-70 Td ground yarn-Ne 30 pile yarn. For the fabrics containing 2.2 sinker, the samples having 70 Td ground yarn have higher AR than that of 90 Td ground yarn on the top surface whereas the samples having Ne 30 pile yarn have higher AR than that of Ne 24 pile yarn on the bottom surface. It is seen that the fabrics with 2.5 sinker containing 90 Td ground yarn have higher AR except sample having 70 Td-Ne 30 yarn. The samples with 2.8 sinker have slightly higher AR on the bottom surface than the other samples except sample having 70 Td-Ne 30 yarn. Additionally for the fabrics with 2.8 sinker, the samples containing Ne 24 pile yarn have higher AR on the top surface, on the contrary, reverse tendency is observed on the bottom surface.

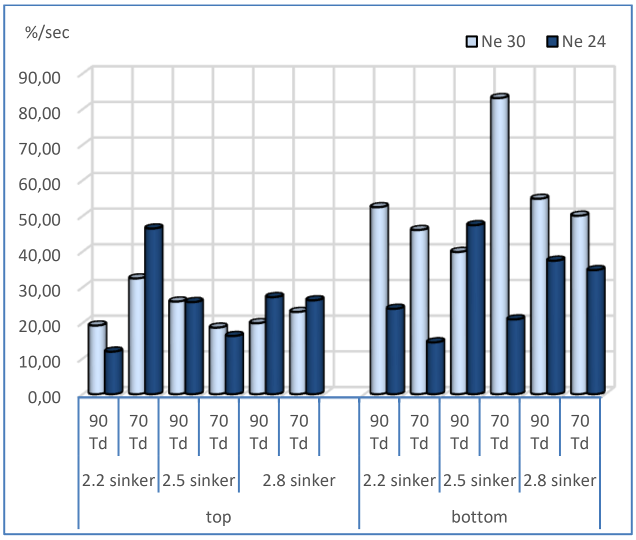

Figure 7. Absorption rate

3.2. Spreading Speed (SS)

The graph showing the spreading speeds of the knitted towel samples is given in Figure 8.

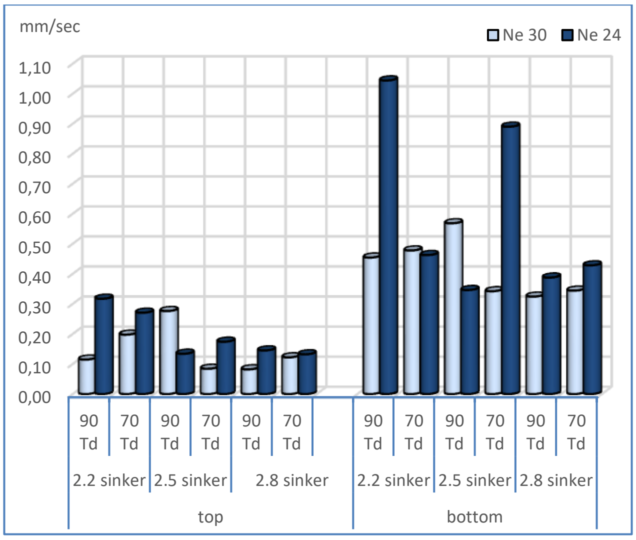

Figure 8. Spreading speed

It is observed from Figure 8 that the bottom SS has higher than top SS for all samples from figure. For the fabrics with 2.2 sinker, the samples having Ne 24 pile yarn have higher SS than the samples having Ne 30 pile yarn on the top surface, whereas SS values of the samples are almost same on the bottom surface except the sample having 90 Td-Ne 24 yarns. The samples of 90 Td-Ne 30 yarns and 70 Td-Ne 24 yarns have higher SS than the other samples in the fabrics with 2.5 sinker. On the other hand, SS values of the samples containing different ground and pile yarns for 2.8 sinker are close to each other.

3.3. One Way Transport Capability (OWTC)

According to Figure 9, the samples with 90Td ground yarn have higher OWTC than the samples with 70 Td ground yarn for the fabrics with 2.2 sinker. Hence the samples having Ne 24 pile yarn have higher OWTC than the samples having Ne 30 pile yarn in these fabrics. On the contrary, the samples with 70 Td ground yarn have higher OWTC than the samples with 90 Td ground yarn for the fabrics with 2.5 sinker whereas OWTC are almost same in the samples having different ground yarn for the fabrics with 2.8 sinker. For the fabrics with 2.5 sinker and 2.8 sinker in terms of the pile yarns, OWTC values of the samples having Ne 24 are higher than that of the samples having Ne 30 in the fabrics with 2.5 sinker whereas the tendency is reverse in the fabrics with 2.8 sinker

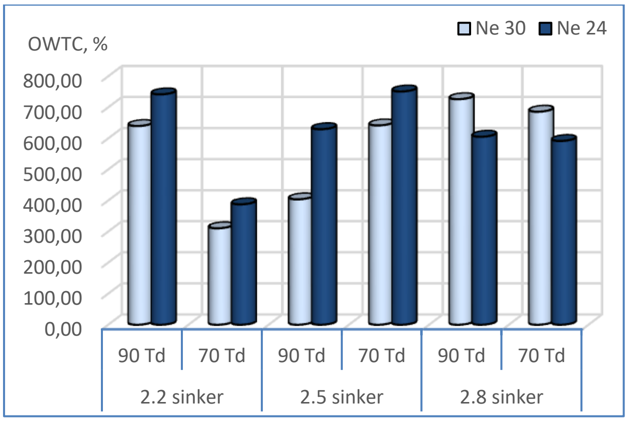

Figure 9. One way transport capability (OWTC)

3.4. Overall Moisture Management Capacity (OMMC)

It is seen from Figure 10 that the samples having Ne 30 pile yarn have higher OMMC than the samples having Ne 24 pile yarn for the fabrics with 2.2 sinker. In the fabrics with 2.5 sinker, the sample containing Ne 30 pile yarn lower OMMC for 90 Td ground yarn, whereas higher OMMC for 70 Td ground yarn. Additionally, OMMC values are same in the samples having Ne 24 pile yarn for the fabrics with 2.5 sinker and all the samples with 2.8 sinker.

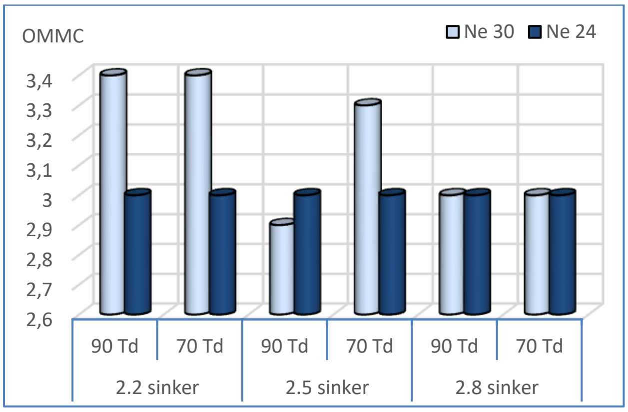

Figure 10. Overall moisture management capacity (OMMC)

Table 6. Regression test results

Factors		Ground yarn		Pile yarn		Pile height	
		t *	Sig. **	t	Sig.	t	Sig.
Absorption rate	Top	-0.181	0.860	0.546	0.599	0.699	0.520
	Bottom	-0.787	0.452	2.155	0.060	-0.162	0.875
Spreading speed	Top	1.504	0.167	0.123	0.905	-0.601	0.563
	Bottom	1.321	0.219	-0.169	0.870	-0.149	0.885
OWTC		0.900	0.392	-0.722	0.489	1.769	0.117
OMMC		1.081	0.308	**3.069**	**0.013**	0.933	0.375

t* Test statistic
Sig.** Significance

According to Table 6, ground yarn and pile height are not effective on the examined moisture management properties. Pile yarn has only effect on OMMC, whereas it has not affect the other properties.

4. Conclusion

As determined in the previous works, it is once again shown that yarn count and pile height have influence on moisture management properties of the fabrics with the study.

The study reveals that bottom absorption rate and spreading speed than that of top for all pile loop knit fabrics. Fabrics with coarse pile yarns (Ne 24) exhibit lower absorbency on the bottom surface than fabrics with fine pile yarns (Ne 30). Fabrics with low sinker height and fine ground yarn have higher top absorption rate whereas fabrics with coarse ground yarn (90 Td) have usually higher bottom absorption rate. The absorption rate values are slightly higher in fabrics with 2.8 sinker.

Fabrics with coarse pile yarn (Ne 24) have higher top spreading speed whereas bottom spreading speed is higher in the fabrics with low sinker height.

OWTC of the fabrics having coarse pile yarn in low sinker height is better, on the contrary, OWTC of the fabrics containing fine pile yarn in high sinker height is better.

As a result, it can be said that moisture management performance (OMMC) is higher in the fabrics having low sinker height, fine ground and pile yarn.

It is suggested that the moisture management performances of pile loop (knitted towel) fabrics should be fully demonstrated by carrying out similar works with different numbers of pile and ground yarns, pile yarns with different raw materials or different pile heights for future studies.

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