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Experimental Investigation of the Effect of Fabric Construction on Dynamic Water Absorbtion in Terry Fabrics

Abstract
Dynamic water absorption properties of terry fabrics were investigated experimentally using 216 various terry fabric samples of different construction. It is shown that around 26% to 40% of water is absorbed during the first 10 seconds, depending on the fabric construction; the percentage of water absorption exceeds 50% in 30 seconds and reaches 75% in 100 seconds. Yarn type is found to have the most important effect on the dynamic water absorption properties of terry fabrics. 29.5 tex ring carded yarn has a faster water absorption than 29.5×2 tex ring carded yarn and 29.5×2 tex open end yarn, and 29.5×2 tex open end yarn has the lowest water absorption speed. The effect of pile length, warp and weft density on the percentage of water absorption remains limited compared to that of yarn type, and no significant effect of these parameters on water absorption is found for the last 100 seconds.

Key words: *terry fabric, terry fabric construction, water absorbtion, dynamic water absorbtion, static water absorbtion.*

Introduction

Terry fabrics have a higher water absorption property compared to other types of textile fabrics, as the end uses of terry fabrics require this. The water absorption capacity of a terry fabric is dependent on yarn material, yarn type and fabric construction. The effect of terry fabric construction on water absorption capacity was investigated experimentally in a previous publication in terms of the static water absorption properties of terry fabrics [1]. It was shown that the type of yarn used in the production of terry fabrics had the most significant effect on the static water absorption properties of terry fabrics. Two-ply ring-carded yarn showed a higher water absorption value than two-ply open-end yarn and single-ply ring-carded yarn. Terry fabric warp density, weft density and pile length also had some effect on static water absorption properties. An increase in weft and/or warp density reduced the percentage of static water absorption, and an increase in pile length increased the percentage static water absorption of terry fabrics. The effect of pile length on static water absorption was found to be more pronounced compared to warp and weft density.

The amount of water that a terry fabric can absorb is important for its end use. However, this does not give any idea as to how quickly a terry fabric absorbs the water, or how water absorption changes with respect to time. This is also very important from the practical point of view. There is a published work on moisture absorption of cotton fibre with respect to time [2]; it shows that water absorption changes exponentially with respect to time. The water absorption properties of fibres have been analysed in other publications [2 - 6]. No research work has been found in the literature investigating the effect of yarn types and terry fabric construction on the time-dependent water absorption properties of terry fabrics, which is termed dynamic water absorption. This paper experimentally investigates the effect of yarn type and fabric construction on the dynamic water absorption properties of terry fabrics. 216 terry fabric samples woven with three different yarn types are used here for measuring dynamic water absorption; these are the same terry fabric samples used for measuring static water absorption [1]. The effect of yarn type (single-ply ring-spun yarn, two-ply ring-spun yarn and open-end yarn), weft density, ground and pile warp densities and pile height on dynamic water absorption properties are investigated.

Table 2. Warp density, weft density and pile types (lengths) of terry fabrics.

Ground warp density, ends/cm	10, 10.5, 11, 11.5, 12, 12.5
Pile warp density, ends/cm	10, 10.5, 11, 11.5, 12, 12.5
Weft density, picks/cm	16, 17.1, 18, 19.5
Pile types	Low, Medium, High

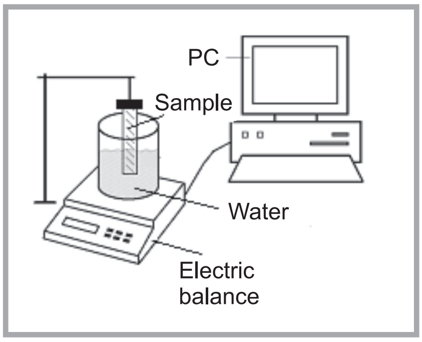


***Figure 1.** Test instrument for dynamic water absorption measurements.*

Table 1. Yarn types used in the production of terry fabrics.

Pile warp yarn	Ground warp yarn	Weft yarn
29.5 tex (Ne20/1) twisted ring spun carded cotton yarn, 760 turns/meter	29.5x2 tex (Ne20/2) twisted ring spun carded cotton yarn, 480 turns/meter	36.9 tex (Ne16/1) ring spun carded cotton yarn, 640 turns/meter
29.5x2 tex (Ne20/2) twisted open-end (OE) cotton yarn, 216 turns/meter	29.5x2 tex (Ne20/2) open-end (OE) cotton yarn, 480 turns/meter	36.9 tex (Ne16/1) open-end (OE) cotton yarn
29.5x2 tex (Ne20/2) twisted ring spun carded cotton yarn, 216 turns/meter	29.5x2 tex (Ne20/2) twisted ring spun carded cotton yarn, 480 turns/meter	36.9 tex (Ne16/1) ring spun carded cotton yarn, 640 turns/meter

Materials and method

Materials

The terry fabrics used in the experimental work were woven using cotton yarns. Three types of yarns were used in the production of terry fabrics. Table 1 shows the properties of weft, ground warp and pile warp yarns.

Table 3. Pile lengths of terry fabrics with three pile yarn types.

Weft density, picks/cm	Pile type	Pile length (in mm)		
		29.5 tex ring spun carded	29.5×2 tex OE	29.5×2 tex ring spun carded
16.0	Low	7.3	6.6	6.8
	Medium	10.8	8.6	9.3
	High	12.3	10.1	11.2
17.1	Low	6.7	6.5	7.1
	Medium	10.6	8.5	9.4
	High	12.0	9.4	11.0
18.0	Low	6.6	6.3	6.6
	Medium	10.5	8.5	9.3
	High	11.9	9.1	11.2
19.5	Low	6.6	6.2	6.6
	Medium	10.1	8.1	9.2
	High	11.8	10.2	11.2

Six different warp densities, four different weft densities and three different pile lengths were used to produce the different terry fabric constructions; these are shown in Table 2.

The pile lengths of the terry fabrics are given in millimetres in Table 3. The terry fabrics were produced with six different warp densities at the same time by using a variable density reed [7]. Terry fabrics with six different warp densities were thus woven for each weft density and pile warp yarn type with the same pile length.

Method

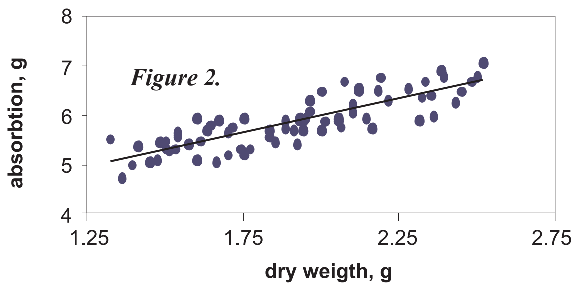
Method of producing the terry fabrics

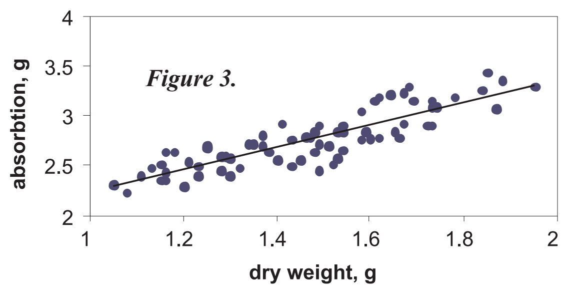
The terry fabrics used in the experiments were woven on a Nouva Pignone TPS 500 model rapier terry weaving machine with a dobby using the three-pick principle. With the combination of six different warp densities, four different weft densities and three different pile heights, 72 different terry fabric constructions were obtained. As this was repeated for three different pile yarn types (i.e. the 29.5 tex ring-spun carded cotton yarn, the 29.5×2 tex ring-spun carded cotton yarn and the 29.5×2 tex OE yarn), a total of 216 different terry fabrics were produced for the experiments.

Before conducting the dynamic water absorption measurements, all the terry fabric samples were subjected to pre-washing processes. However, no hydrophilic finishes were applied. Pre-washing was applied to all terry fabric samples to remove the sizing substance, paraffin and oil remnants.

Dynamic water absorption measurement

Dynamic water absorption measurements were based on the Bureau Veritas Consumer Products Services BV S1008 internal test method. According to this method, the terry fabric sample is cut into pieces of 25×150 mm dimensions. This fabric sample is plied from its middle and made two-ply in 25×75 mm dimensions. Later, a 12.5-mm part of the sample is attached to a holder as shown in Figure 1, and the bottom 25-mm part of the fabric sample is left inside the water in a beaker. As the fabric sample does not touch the beaker, it does not affect the electronic balance's measurement. This shows only the weight of the water inside the beaker. As the terry fabric sample starts to absorb water, the weight indicated by the electronic balance decreases over time. The amount of the decrease in weight measured by the electronic balance corresponds to the water absorbed by the terry fabric sample. In this way, the water absorbed by a terry fabric sample is measured over time. An electronic balance made by Sortius is used in the weight measurements, and the weight measurement data is transferred from the electronic balance to a computer using Sartoconnect data transfer software. Weight measurement is carried out over 300 seconds for each terry fabric sample. As each fabric sample has a different construction, the dynamic water absorption test results can be assessed for different fabric constructions and fabric parameters.





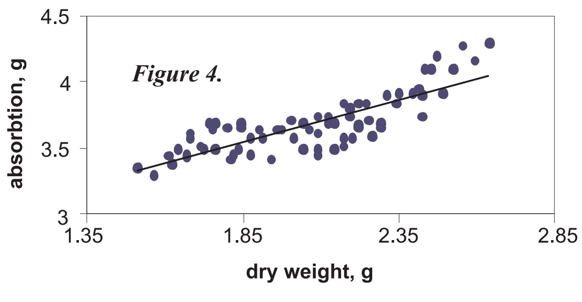


Figure 2. *Water absorption (in g)/dry sample weight relationship for 29.5×2 tex ring-carded yarn. Y = 1.374 X + 3.252, Y: Water absorption in g, X: Dry sample weight in g.* $R^2 = 0.7066$.

Figure 3. *Water absorption (in g)/dry sample weight relationship for 29.5 tex ring-carded yarn. Y = 1.124 X + 1.115, Y: Water absorption in g, X: Dry sample weight in gr.* $R^2 = 0.7415$.

Figure 4. *Water absorption (in g)/dry sample weight relationship for 29.5×2 tex open-end yarn. Y = 0.6311 X + 2.3858, Y: Water absorption in g, X: Dry sample weight in gr.* $R^2 = 0.6666$.

Table 4. *Change of amount of water absorbtion (in g) depending on pile length for six different time intervals.*

Yarn type	Pile length	Water absorbed, g over the period of:					
		0-10 s	10-30 s	30-100 s	100-200 s	200-300 s	0-300 s
29.5x2 tex ring carded	Low	1.69	1.51	0.73	0.96	0.58	5.47
	Medium	1.88	1.45	0.84	1.05	0.62	5.84
	High	2.10	1.34	0.99	1.19	0.66	6.28
29.5 tex ring carded	Low	1.00	0.53	0.40	0.40	0.21	2.54
	Medium	1.07	0.58	0.41	0.43	0.23	2.72
	High	1,21	0,67	0,39	0,53	0,24	3.04
29.5x2 tex OE	Low	0.94	0.91	0.86	0.47	0.36	3.54
	Medium	0.98	0.97	0.84	0.48	0.39	3.66
	High	1.06	0.95	0.85	0.58	0.40	3.84

Table 5. *Change of amount of water absorbtion (in g) depending on weft density for six different time intervals.*

Yarn type	Weft density, ends/cm	Water absorbed, g over the period of:					
		0-10 s	10-30 s	30-100 s	100-200 s	200-300 s	0-300 s
29.5x2 tex ring carded	16.0	1.71	1.43	0.96	0.98	0.61	5.69
	17.1	1.86	1.43	0.80	0.99	0.62	5.70
	18.0	1.94	1.43	0.84	1.17	0.63	6.01
	19.5	2.06	1.43	0.82	1.10	0.64	6.05
29.5 tex ring carded	16.0	0.98	0.54	0.40	0.40	0.19	2.51
	17.1	1.06	0.62	0.40	0.41	0.23	2.72
	18.0	1.14	0.60	0.38	0.49	0.25	2.86
	19.5	1.19	0.61	0.44	0.47	0.25	2.96
29.5x2 tex OE	16.0	0.89	0.91	0.84	0.51	0.33	3.48
	17.1	0.93	1.07	0.71	0.48	0.39	3.58
	18.0	1.02	0.98	0.85	0.51	0.40	3.76
	19.5	1.13	0.92	0.90	0.53	0.41	3.89

Table 6. *Change of amount of water absorbtion (in g) depending on warp density for six different time intervals.*

Yarn type	Warp density, ends/cm	Water absorbed, g over the period of:					
		0-10 s	10-30 s	30-100 s	100-200 s	200-300 s	0-300 s
29.5x2 tex ring carded	10.0	1.78	1.29	0.87	0.94	0.59	5.47
	10.5	1.86	1.33	0.81	0.97	0.60	5.57
	11.0	1.86	1.43	0.82	1.02	0.61	5.74
	11.5	1.92	1.44	0.85	1.08	0.63	5.92
	12.0	1.95	1.52	0.87	1.18	0.64	6.16
	12.5	1.99	1.57	0.90	1.18	0.66	6.3
29.5 tex ring carded	10.0	1.00	0.56	0.44	0.47	0.22	2.69
	10.5	1.05	0.55	0.45	0.44	0.23	2.72
	11.0	1.06	0.58	0.41	0.41	0.23	2.69
	11.5	1.10	0.61	0.41	0.43	0.24	2.79
	12.0	1.14	0.63	0.35	0.46	0.23	2.81
	12.5	1.20	0.63	0.35	0.47	0.24	2.89
29.5tex OE	10.0	0.91	0.91	0.89	0.52	0.35	3.58
	10.5	0.96	0.93	0.86	0.54	0.37	3.66
	11.0	1.02	0.90	0.85	0.51	0.38	3.66
	11.5	1.03	0.92	0.86	0.52	0.38	3.71
	12.0	1.00	1.00	0.83	0.49	0.4	3.72
	12.5	1,04	1.00	0.81	0.49	0.41	3.75

Results and discussions

Relation between water absorption over 300 seconds and fabric weight

An increase in pile length, warp density and/or weft density causes an increase in fabric weight per unit area, and therefore the water absorption capacity of a terry fabric increases. Figures 2, 3 and 4 show the relationship between water absorption over 300 seconds (in g)and the dry sample weight for 29.5×2 tex ring-carded, 29.5 tex ring-carded and 29.5×2 tex open-end yarns respectively. In all three cases, a linear relationship is observed between water absorption over 300 seconds and the dry sample weight. The coefficient of regression indicates the existence of a good relationship between these two parameters. The slope of three linear curves shows that water absorption increases at the highest rate with respect to dry sample weight in the case of the 29.5×2 tex ring-carded yarn, and at the lowest rate with the 29.5×2 tex open-end yarn. In the case of 29.5 tex ring carded yarn, the increase in water absorption with respect to dry sample weight is greater than that of the 29.5×2 tex open-end yarn, and lower than the 29.5×2 tex ring carded yarn. The increase in water absorption with respect to the dry sample weight is significantly lower in the 29.5×2 tex open-end yarn than in the 29.5×2 tex and 29.5 tex ring-carded yarns. This result is in agreement with the static water absorption results [1].

Dynamic water absorption behaviour of terry fabrics

The dynamic water absorption properties of terry fabrics have been investigated with respect to yarn type, yarn number, warp and weft densities and pile height.

Figure 5 (see page 78) shows the water absorption behaviour of terry fabrics over time for three different yarn types. Although these three curves correspond to the three fabric samples, all the fabric samples show the same water absorption characteristics over time. As seen from the curves, water is absorbed very quickly at the start (approximately up to 30 seconds), and then the water absorption speed decreases significantly. For this reason, in this paper the first 30 seconds is termed the quick absorption period, and the rest (30 to 300 seconds) as the slow absorption period. Regression analysis was applied to the experimental data of water absorption, and the logarithmic curves showed a very good match with the experimental data. The high coefficient of regression (R^2) proves that this is a very good match for all three yarn types. In Figure 5, the dotted curves represent the experimental results, and the continuous ones represent the matched curves.

For more quantitative analysis, the amount of water absorption in grams is given in Table 4, 5 and 6 for pile length, weft density and warp density respectively for six different time intervals up to 300 seconds. The quick water absorption period was divided into two sub-intervals, 0 to 10 and 10 to 30 seconds. The 0 to 10-second interval is important as water is absorbed at the highest rate in this interval. The slow water absorption period was divided into three intervals; 30 to 100, 100 to 200 and 200 to 300 seconds. The total amount of water absorbed in 300 seconds is also given in the tables. Increases in pile length, weft density and warp density cause an increase in the amount of water absorbed during all of the five time intervals and in 300 seconds; this is due to generally the increases in sample weight. More than one-fourth of the total water absorption takes place in the first 10 seconds, and more than half of the total water absorption takes place in the first 30 seconds for all fabric samples. It is clearly seen in all three tables that yarn type has the most significant effect on dynamic water absorption.

As the amount of water absorbed in 300 seconds depends on the fabric weight, it would be more suitable to use the percentages of dynamic water absorption as the basis for comparing the dynamic water absorption properties of the different fabric constructions. Tables 7, 8 and 9 show the percentages of water absorptions of five different time intervals for different pile lengths, weft densities and warp densities respectively. The percentage of water absorption for a given time interval was calculated by dividing the amount of water absorbed in this interval by the amount of water absorbed in 300 seconds and then multiplying it by 100. In all three tables, the effect of pile length, weft density and warp density on water absorption is limited compared to that of yarn type.

In the first 10 seconds, water absorptions of 39.5% for 29.5 tex ring-carded yarn, 32.0% for 29.5×2 tex ring-carded yarn and 26.5% for open-end yarn are noted. Only a small change occurs in the percentages of water absorption when pile length, weft density or warp density fluctuate between their minimum and maximum values. This small change in the percentage of absorption does not follow a regular increase or decrease with an increase in pile length, weft density or warp density. In the second interval between 10 to 30 seconds, average water absorptions of 24.5% for 29.5×2 tex ring-carded yarn, 21.5% for 29.0 tex ring-carded yarn and 26.0% for open-end yarn are noted. No significant change occurs in the percentages of water absorption for open-end yarn between the first and second intervals. It decreases more with the 29.5 tex ring-carded yarn than the 29.5×2 tex ring-carded yarn. At the end of 30 seconds, the percentage of water absorption reaches 56.5% for 29.5×2 tex ring-carded yarn, 61.0% for 29.5 tex ring-spun yarn and 52.5% for 29.5×2 tex open-end yarn. These results show that more than half of the total water absorbed in 300 seconds is completed in one-tenth of the total water absorption period. After 100 seconds, water absorption reaches 75.0% for all fabric samples. In the slow absorption period, the percentages of water absorption come closer to each

Table 7. *Percent water absorbtion of five time intervals for different pile lengths.*

Yarn Type	Pile Length	Percentage of water absorbed over the period of:					
		0-10 s	10-30 s	30-100 s	100-200 s	200-300 s	0-300 s
29.5x2 tex ring carded	Low	30.90	27.60	13.35	17.55	10.60	100.00
	Medium	32.19	24.83	14.38	17.98	10.62	100.00
	High	33.44	21.34	15.76	18.95	10.51	100.00
29.5 tex ring carded	Low	39.37	20.87	15.75	15.75	8.27	100.00
	Medium	39.34	21.32	15.07	15.81	8.46	100.00
	High	39.80	22.04	12.83	17.43	7.89	100.00
29.5x2 tex OE	Low	26.55	25.71	24.29	13.28	10.17	100.00
	Medium	26,78	26.50	22.95	13.11	10.66	100.00
	High	27,60	24.74	22.14	15.10	10.42	100,00

Table 8. *Percent water absorbtion of five time intervals for different weft densities.*

Yarn type	Weft density, ends/cm	Percentage of water absorbed over the period of:					
		0-10 s	10-30 s	30-100 s	100-200 s	200-300 s	0-300 s
29.5x2 tex ring carded	16.0	30.05	25.13	16.87	17.22	10.72	100.00
	17.1	32.63	25.09	14.04	17.37	10.88	100.00
	18.0	32.28	23.79	13.98	19.47	10.48	100.00
	19.5	34.05	23.64	13.55	18.18	10.58	100.00
29.5 tex ring carded	16.0	39.04	21.51	15.94	15.94	7.57	100.00
	17.1	38.97	22.79	14.71	15.07	8.46	100.00
	18.0	39.86	20.98	13.29	17.13	8.74	100.00
	19.5	40.20	20.61	14.86	15.88	8.45	100.00
29.5x2 tex OE	16.0	25.57	26.15	24.14	14.66	9.48	100.00
	17.1	25.98	29.89	19.83	13.41	10.89	100.00
	18.0	27.13	26.06	22.61	13.56	10.64	100.00
	19.5	29.05	23.65	23.14	13.62	10.54	100.00

Table 9. *Percent water absorbtion of five time intervals for different warp densities.*

Yarn Type	Warp Desity (ends/cm)	Percentage of water absorbed over the period of:					
		0-10 s	10-30 s	30-100 s	100-200 s	200-300 s	0-300 s
29.5x2 tex ring carded	10.0	32.54	23.58	15.90	17.18	10.79	100.00
	10.5	33.39	23.88	14.54	17.41	10.77	100.00
	11.0	32.40	24.91	14.29	17.77	10.63	100.00
	11.5	32.43	24.32	14.36	18.24	10.64	100.00
	12.0	31.66	24.68	14.12	19.16	10.39	100.00
	12.5	31.59	24.92	14.29	18.73	10.48	100.00
29.5 tex ring carded	10.0	37.17	20.82	16.36	17.47	8.18	100.00
	10.5	38.60	20.22	16.54	16.18	8.46	100.00
	11.0	39.41	21.56	15.24	15.24	8.55	100.00
	11.5	39.43	21.86	14.70	15.41	8.60	100.00
	12.0	40.57	22.42	12.46	16.37	8.19	100.00
	12.5	41.52	21.80	12.11	16.26	8.30	100.00
29.5x2 tex OE	10.0	25.42	25.42	24.86	14.53	9.78	100.00
	10.5	26.23	25.41	23.50	14.75	10.11	100.00
	11.0	27.87	24.59	23.22	13.93	10.38	100.00
	11.5	27.76	24.80	23.18	14.02	10.24	100.00
	12.0	26.88	26.88	22.31	13.17	10.75	100.00
	12.5	27.73	26.67	21.60	13.07	10.93	100.00

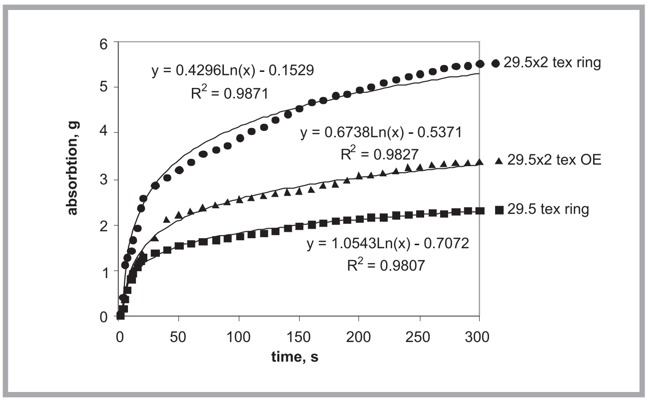


Figure 5. Change of water absorption in terry fabrics with respect to time (warp density: 10 ends/cm, weft density: 16 picks/cm and pile length: low).

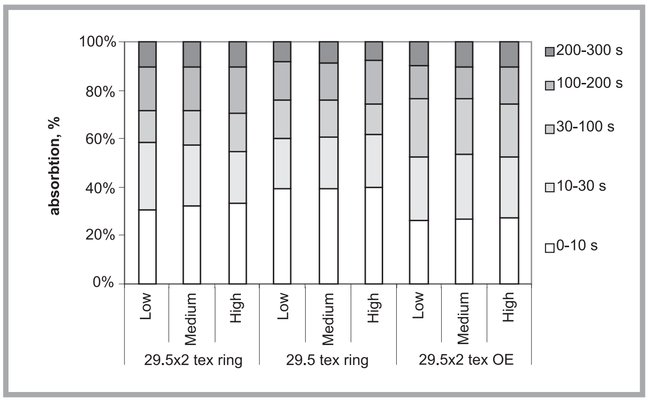


***Figure 6.** Percentages of water absorption for different pile heights.*

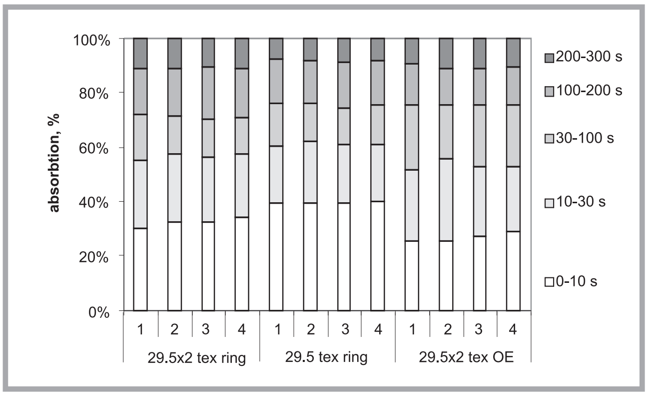


***Figure 7.** Percentages of water absorption for different weft densities (1: 16 picks/cm; 2: 17.1 picks/cm; 3: 18 picks/cm; 4: 19.5 picks/cm).*

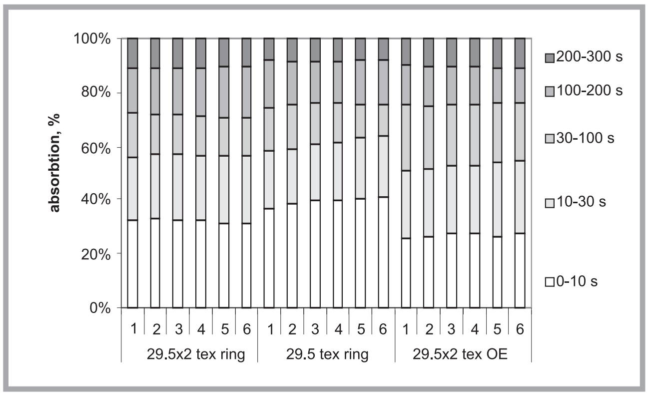


***Figure 8.** Percentages of water absorption for different warp densities (1: 10 ends/cm; 2: 10.5 ends/cm; 3: 11 ends/cm; 4: 11.5 ends/cm; 5: 12 ends/cm; 6: 12.5 ends/cm).*

other for all three yarn types, and only 8.0 to 10.0% of water absorption occurs in the last 100 seconds. Water absorption speed does not reach zero at the end of 300 seconds, but it decreases to a very low value, which is not significant from the practical point of view. Even when the test period was extended to 600 seconds, water absorption continued, but at a very low speed.

The percentage of water absorption data presented in Table 7, 8 and 9 are shown graphically in Figures 6, 7 and 8 respectively. A three-factor Anova statistical test was applied to the data in each time interval to determine the effect of terry fabric parameters (warp density, weft density and pile length) on the percentages of water absorption.

According to the Anova test results obtained, with 95% confidence interval (α = 0.05), it was found that weft density had the most significant effect and the pile height had the second most significant effect on the percentages of water absorption over 10 seconds for 29.5×2 tex ring-carded yarn. In the case of 29.5 tex ring-carded yarn, warp density had the most significant effect and weft density had the second most significant effect on percentages of water absorption over 10 seconds. Pile length was found to have the least significant effect. For 29.5×2 tex open-end yarn, weft density had the most significant effect on percentages of water absorption over 10 seconds. Pile height had the second important effect, and warp density had the least effect. Over 30 seconds, pile length had the most significant effect and weft density had the second most significant effect on percentages of water absorption for 29.5×2 tex ring-carded yarn. For 29.5 tex ring-carded yarn, the importance of order of the parameters was found to be warp density, pile length and weft density. This order of importance is warp density, weft density and pile length for 29.5×2 open-end yarn. In 100 seconds, weft density had the most significant effect on percentages of water absorption, followed by pile length and warp density for both 29.5×2 and 29.5 tex ring-carded yarns. In the case of 29.5×2 open-end yarn, pile length had the most and weft density had the least significant effect on percentages of water absorption. According to the Anova test results, no effect of warp and weft densities or pile height on percentages of water absorption over the final 100 seconds was noted for 29.5×2 tex ring-carded yarn. For 29.5 tex ring-carded yarn, pile height and weft density had some effect, and for 29.5×2 tex open-end yarn weft density, warp density and pile height had a very small effect on percentages of water absorption over the final 100 seconds.

It is understood from the analysis of the data presented in the figures and tables that the dynamic water absorption behaviour of terry fabrics is determined mainly by the yarn type used in the production of terry fabrics. Pile length, warp density and weft density have only limited effect on dynamic water absorption. These three terry fabric parameters affect the amount of water absorbed in grams as they determine the fabric weight for a certain yarn type. Open-end yarn has lower water absorption in grams, and water absorption is slower compared to ring-carded yarns. Although ring-yarn structure is more compact than that of open-end yarns, higher twist is applied to open-end yarns during production due to the shorter fibre length of open-end yarns. This makes the open-end yarn's structure more difficult for the water to penetrate. 29.5×2 double ply ring-carded yarns has slower water absorption compared to 29 tex ring-carded yarn. This is thought to be due to the twist of double ply yarn. As two 29 tex yarns are brought together and twisted to produce two-ply yarn, the twist applied to double-ply yarn makes the structure tighter. Therefore, water penetrates quicker to single-ply ring yarns than double-ply ring yarns.

Dynamic water absorption speed

In the above discussions, the water absorption values have been given in grams and in percentages over time. We assumed that presenting water absorption data as water absorption speed (gram per second) for each time interval would provide a more direct understanding of the dynamic water absorption behaviour of terry fabrics. Water absorption speed is calculated by dividing the amount of water absorbed in grams by the time interval; in this way, average water absorption speeds are obtained for each time interval. The results are presented in Table 10, 11 and 12 for different pile heights, weft densities and warp densities respectively. In all three tables, water absorption speed increases with the increase in pile length, weft density and warp density in the period of the first 10 seconds. This is due to the increase in fabric weight with increasing pile length and weft and warp densities. The increase in water absorption speed with increasing pile length, weft and warp densities becomes lower between 10 to 30 seconds compared to the first 10-second period. In the slow water absorption period (after 30 seconds), no significant change occurs in water absorption speed with the increases in pile length or weft and warp densities. Analysis of water absorption speeds over five time intervals in all three tables shows that water absorption speed is 5 to 15 times higher in the quick water absorption period (0 to 10 seconds and 10 to 30 seconds) than in the slow water absorption period. Only small changes occur in water absorption speeds in slow water absorption time intervals (30 to 100 seconds, 100 to 200 seconds and 200 to 300 seconds).

Table 10. *Water absorption rate (in g/s) for different pile lengths.*

Yarn type	Pile length	Water absorbtion rate, g/s over the period of:				
		0-10 s	11-30 s	31-100 s	101-200 s	201-300 s
29.5×2 tex ring carded	low	0.169	0.076	0.010	0.010	0.006
	medium	0.188	0.073	0.012	0.011	0.006
	high	0.210	0.067	0.014	0.012	0.007
29.5 tex ring carded	low	0.100	0.027	0.006	0.004	0.002
	medium	0.107	0.029	0.006	0.004	0.002
	high	0.121	0.034	0.006	0.005	0.002
29.5×2 tex OE	low	0.094	0.046	0.012	0.005	0.004
	medium	0.098	0.049	0.012	0.005	0.004
	high	0.106	0.048	0.012	0.006	0.004

Table 11*. Water absorption rates (in g/s) for different weft densities.*

Yarn type	Weft density, ends/cm	Water absorbtion rate, g/s over the period of:				
		0-10 s	11-30 s	31-100 s	101-200 s	201-300 s
29.5×2 tex ring carded	16.0	0.171	0.072	0.014	0.010	0.006
	17.1	0.186	0.072	0.011	0.010	0.006
	18.0	0.194	0.072	0.012	0.012	0.006
	19.5	0.206	0.072	0.012	0.011	0.006
29.5 tex ring carded	16.0	0.098	0.027	0.006	0.004	0.002
	17.1	0.106	0.031	0.006	0.004	0.002
	18.0	0.114	0.030	0.005	0.005	0.003
	19.5	0.119	0.031	0.006	0.005	0.003
29.5×2 tex OE	16.0	0.089	0.046	0.012	0.005	0.003
	17.1	0.093	0.054	0.010	0.005	0.004
	18.0	0.102	0.049	0.012	0.005	0.004
	19.5	0.113	0.046	0.013	0.005	0.004

Table 12. *Water absorption rate (in g/s) for different warp densities.*

Yarn type	Warp density (ends/cm)	Water absorbtion rate, g/s over the period of:				
		0-10 s	11-30 s	31-100 s	101-200 s	201-300 s
29.5×2 tex ring carded	10.0	0.178	0.065	0.012	0.009	0.006
	10.5	0.186	0.067	0.012	0.010	0.006
	11.0	0.186	0.072	0.012	0.010	0.006
	11.5	0.192	0.072	0.012	0.011	0.006
	12.0	0.195	0.076	0.012	0.012	0.006
	12.5	0.199	0.079	0.013	0.012	0.007
29.5 tex ring carded	10.0	0.100	0.028	0.006	0.005	0.002
	10.5	0.105	0.028	0.006	0.004	0.002
	11.0	0.106	0.029	0.006	0.004	0.002
	11.5	0.110	0.031	0.006	0.004	0.002
	12.0	0.114	0.032	0.005	0.005	0.002
	12.5	0.120	0.032	0.005	0.005	0.002
29.5×2tex OE	10.0	0.091	0.046	0.013	0.005	0.004
	10.5	0.096	0.047	0.012	0.005	0.004
	11.0	0.102	0.045	0.012	0.005	0.004
	11.5	0.103	0.046	0.012	0.005	0.004
	12.0	0.100	0.050	0.012	0.005	0.004
	12.5	0.104	0.050	0.012	0.005	0.004

Conclusion

The following conclusions can be drawn from this research:

- Water is initially absorbed very quickly by terry fabrics. Depending on the yarn type, around 26-40% of the total water absorption capacity is absorbed in the first 10 seconds. The percentage of water absorption reaches up to 50% to 65% in the first 30 seconds. After 30 seconds, water absorption continues at a decreasing speed. In the final 100 seconds, only 8-10% of water is absorbed. Water absorption continues even after 300 seconds but at a very low rate, which cannot be considered from the practical viewpoint. Such a water absorption characteristic of terry fabrics matches the logarithmic curves very well.

- Among the fabric parameters, yarn type has the most significant effect on dynamic water absorption properties of terry fabrics. 29.5 tex ring-carded yarn has a quicker water absorption than 29.5×2 tex ring-carded yarn and 29.5×2 tex open-end yarn. Furthermore, it reaches saturation earlier than the other two yarn types. 29.5×2 tex open-end yarn has the lowest water absorption rate.
- Warp density, weft density and pile height have only a small effect on the percentage of the water absorption speed of terry fabrics, which is not worth considering when designing them.
- There are different methods of measuring dynamic water absorption. The results obtained in this paper may not be useful for certain specific applications. Therefore, conducting experiments using different methods will give a much better understanding of the dynamic water absorption properties of terry fabrics.

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