

## Theoretical Prediction of Overall Porosity of Terry Woven Fabrics

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### Abstract

A new geometrical model of terry woven fabrics made with cotton yarn has been analyzed to understand the pile yarn path. Theoretical model has been created to predict the porosity of terry woven fabrics depending on their geometrical such as warp and weft spacing pile length pile height pile ratio (terry ratio) type of terry yarn count yarn crimp fabric thickness yarn density and fiber density. Cotton terry woven fabrics were produced with different parameters namely pile height picks per cm and weft yarn count their porosity was determined by measuring fabric density and fiber density and compared with the theoretical porosity. The validity of the theoretical model was confirmed by experimental results. Experiments show that this model gives good results.

**Keywords:** Porosity; Terry woven fabric; Theoretical model; Terry ratio; Pile height; Fabric thickness; Fibre density; Prediction

### Nomenclature

Mf	Mass of fibres in the fabric g
MF	Mass of fabric g
H	Pile height cm
L	The length of loop of pile yarn cm <sup>3</sup>
Vc	The volume of the cuboid of the fabric sample cm <sup>3</sup>
VP	The volume of pile warp yarns in the cuboid cm <sup>3</sup>
Vg	The volume of ground warp yarns in the cuboid cm <sup>3</sup>
Vw	The volume of weft yarns in the cuboid cm <sup>3</sup>
mp	The weight of pile yarns in the cuboid g
Nmp	The metric count of pile warp yarn Nm
Nmg	The metric count of ground warp yarn Nm
Nmf	The metric count of weft yarns Nm
$\rho_{yg}$	The density of ground warp yarn g/cm <sup>3</sup>
$\rho_{yf}$	The density of filling yarn g/cm <sup>3</sup>
C1	The crimp of ground warp yarn %
C2	The crimp of filling yarn %
Sw	Static water absorption %
Mw	The weight of wet samples g
Md	The weight of dry samples g
M	Fabric surface density g/m <sup>2</sup>

### Introduction

Porosity is a vital quality in such end – use applications as sport garments, underwear products T- shirts socks and others. Porosity also significantly influences the thermal comfort of the human body for the proper body temperature [1].

Porosity is the most important property that affects the absorption capacity of the material. Porosity is used to describe the porous structure of textile materials. It is defined as the ratio of the void space in a porous medium over the total bulk volume of the medium. It is a

dimensionless quantity and can range between 0 and 1 [2]. The amount of porosity i.e., the volume fraction of voids within the fabric determines the capacity of a fabric to hold water the greater the porosity the more water the fabric can hold [3]. The porosity and size of capillary of terry woven fabric will influence its physical properties such as bulk density liquid uptake the mass transfer and the thermal conductivity.

It is logical to expect that fabric structure has an impact on porosity [4]. The structure of a textile contains pores between the fibres and the yarns. It is quite clear that pore dimension and distribution is a function of the fabric geometry. The yarn diameter surface formation techniques number of yarn threads per unit length (yarn density) pile height and number of pile loops for terry woven fabrics per unit area are the main factors affecting the porosity of textiles. The porosity of a fabric is connected with certain important features of it such as air permeability water permeability and dyeing properties etc. [5-7].

There are several different methods available for the assessment of the parameters of porosity, such as: geometrical methods [8-10] liquid intrusion methods [11-13] liquid extrusion methods [14-16] liquid through methods [17] etc. but they can only be used after a fabric is produced. An exception to this is the method based on an ideal geometrical model of an individual textile product as a porous material along with input data. Such a method does not need expensive laboratory equipment or sample weaving. Currently the results of this geometrical method based an ideal model of a porous structure do not compare well with real values determined by other methods. Some of the other methods used for estimating the porosity can only give truly very approximate values which may not be accurate enough. On the other hand some of them are not capable of estimating all the relevant porosity parameters.

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**Received** October 07, 2015; **Accepted** October 19, 2015; **Published** October 27, 2015

**Citation:** Abo-Taleb H, El-Fowaty H, Sakr A (2015) Theoretical Prediction of Overall Porosity of Terry Woven Fabrics. J Textile Sci Eng 5: 217. doi:10.4172/2165-8064.1000217

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All models that lead to the determination of the porosity of woven fabric include some simplifying assumptions which introduce some inaccuracies into the result. Therefore it is very difficult to find the optimal method that predicates the permeability or porosity of the woven fabric.

A lot of work has been done over the years to overcome the mentioned shortcomings. Some researchers used a more theoretical approach [18-22], while some used a more experimental approach [23-25].

Some previous studies investigated the relationship between porosity and structural characteristics of woven fabrics such as fabric weight thickness density or finishing process [26-35].

In previous studies to predict the porosity of woven fabrics only the porosity of interyarn interstices was considered and interstices of interfibre were omitted [28,36-40]. However Xu and Wang [41] used the stepwise regression method to explore the permeability of interfibre interstices. In the present study the overall porosity through interstices of fibers and yarns together was calculated. So more realistic results can be achieved than previous studies.

Although the prediction of porosity of woven fabrics has been described previously in the literature [26,28,40,42], no work has yet been carried out to predict the porosity of terry woven fabrics.

In spite of the availability of other porosity testers very little work has been done to correlate the porosity of a woven fabric with its structural properties.

The aim of this paper is to demonstrate theoretical model created to predict the porosity of terry woven fabric. The model will enable the engineering of terry woven fabrics to a required porosity thus determining other properties such as absorbency rate and liquid retention.

The object of this study was selected because of a lack of research dealing with investigations into the behavior of terry structure when in contact with liquid in general.

In this study a new geometrical model has been analyzed to understand the pile yarn path of terry woven fabrics. This method is suitable for all types of terry woven fabrics.

## Theoretical Model

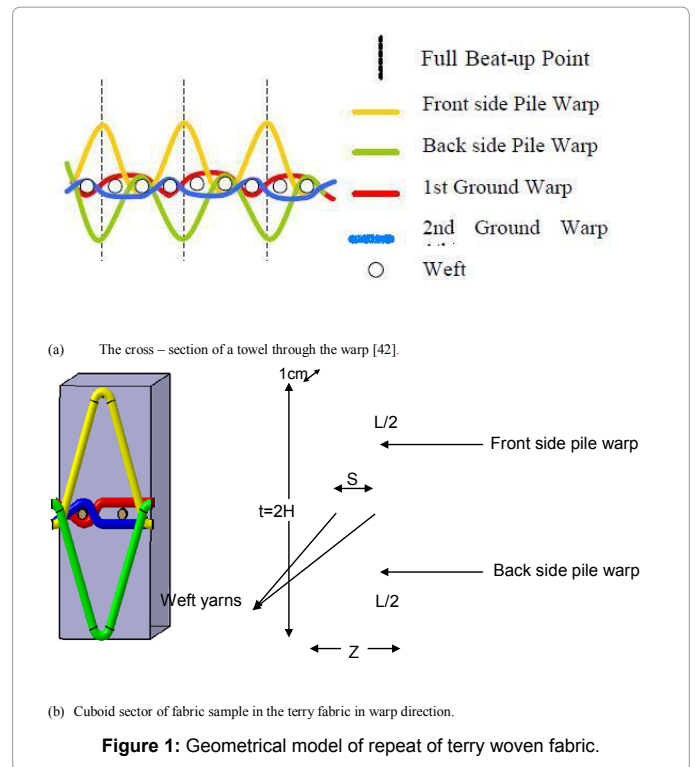
### Assumptions

- The pile yarns in the terry woven fabric lies in a zigzag path with triangle shapes for both front and back surfaces as shown in Figure 1.
- The air space in the pile yarn consists of very fine circular capillaries which are parallel to the pile yarn and have the same length as the pile yarn.
- Fibres are equally distributed within the yarns as there are no external compression forces.

### Ideal geometrical model of a terry woven fabric

Our experiments were carried out with cotton terry woven fabrics that have pile loops on both sides. The reason for the selection was the popularity of terry fabrics in home, sauna and leisure textiles such as towels, dressing – gowns, slippers head gear etc. The structure and weave repeat can be seen in Figure 1a.

As seen in Figure 1a ground warp ( $G_1$ ) which is up at the beginning



goes down and ( $G_2$ ), which is first down and then goes upwards through the two yarns. Back side pile (Bp) warp is always opposite to the pile (Fp) warp of the front side. When the (Bp) warp makes the first loop on one side of the fabric a second loop will be formed on the other side. The (Fp) warp operates in a similar fashion.

In the present work the terry woven fabrics are assumed to be of different pile heights, different yarn diameters different warp spacing's and of different weft spacing's as a general case. The geometrical model of terry woven fabrics is shown in Figure 1.

A cuboid sector of fabric with thickness (t) and width (z) with 1 cm in length can be taken into consideration for calculating the overall porosity.

Each repeat of this geometrical model is consisted of front and back pile yarns, two ground warps and two weft yarns.

For the calculation of overall porosity, it was assumed that the pile warp yarns in the front and back sides of terry woven fabrics lies in a zigzag path as shown in Figure 1b. If the number of spaces (weft spacing) displaced from the beginning of pile warp yarn to the next pile on both front and back surfaces (floats) is S, then the yarn makes a rhombus layout as shown in Figure 1b.

The width of the cuboid Z can be given as follows:

$$Z = ns \times \text{weft spacing} (P1) = n_s / n_2 \text{ cm} \quad (1)$$

Where  $n_2$  is picks per cm.  $n_s$  is number of spaces S

### Theoretical model derivation

When a terry woven fabric is treated as a three – dimensional formation void spaces (pores) can be situated between fibres in the yarns and between warp and weft threads in the fabric.

Figure 1b shows an ideal geometrical model of the porous structure

of a terry woven Fabric. To compare terry woven fabrics with porosity the following parameters are commonly used : area of the pore cross section pore area distribution pore density equivalent pore diameter maximum and minimum pore diameters pore length pore volume and the portion of the open area the portion of pore volume etc.

The overall porosity of a terry woven fabric ( $\epsilon$ ) can be theoretically calculated on the basis of packing factor ( $\phi$ ) as follows:

$$\epsilon = 1 - \phi \tag{2}$$

The fabric packing factor expresses the ratio of fibre volume ( $V_f$ ) with regard to the fabric volume ( $V_p$ ):

$$\phi = \frac{\rho_f}{\rho} = \frac{m_f}{V_f} \times \frac{V_f}{m_f} \tag{3}$$

Where the symbols  $V$ (cm<sup>3</sup>)  $m$  (g) and  $\rho$  (g/cm<sup>3</sup>) stand for volume mass and specific density respectively. Subscripts f and F denote fibre and woven fabric.

The fabric mass is actually the mass of fibres used ( $m_f=m_p$ ) so the expression given by Equation (3) can be simplified:

$$\phi = V_f / V_p \tag{4}$$

By considering the geometry of a woven fabric shown in Figure 1 the volume of the cuboid ( $V_c$ ) of the fabric sample can be calculated by using the following Equation (5).

$$V_c = \text{length of fabric} \times \text{width} \times \text{thickness.} \tag{5}$$

$$V_c = 1 \text{ cm} \times (n_s/n_2) \text{ cm} \times t \text{ cm} = (n_s/n_2) * t \text{ cm}^3$$

Where fabric thickness (t) is measured under a pressure of 10 g/cm<sup>2</sup>.

Thus the length of loop pile yarn (L) through the width (Z) can be calculated as follows:

$$L = 2\sqrt{H^2 + \left(\frac{Z}{2}\right)^2} = 2\sqrt{\left(\frac{t}{2}\right)^2 + \left(\frac{Z}{2}\right)^2}, \text{cm}$$

$$L = 2\sqrt{\frac{t^2}{4} + \left(\frac{n_s}{2n_2}\right)^2} = 2\sqrt{\frac{t^2}{4} + \frac{n_s^2}{4n_2^2}}, \text{cm} \tag{6}$$

Where H is pile height in cm.

If we consider the fibre volume ( $V_p$ ) is the volume of pile warp yarns in the cuboid and the weight ( $m_p$ ) is the weight of pile yarns in the cuboid then.

Volume of material ( $V_p$ ) in cm<sup>3</sup> =  
 = weight of pile yarn (fibre)/fibre density  
 Weight of material ( $m_p$ ) in grams =  
 = total pile yarn length in both sides in metre/pile yarn count ( $N_{mp}$ )

$$\text{Thus, } V_p = \frac{2L(\text{metre})}{N_{mp} \times \rho_f} \times \frac{\text{ends/cm}}{2}, \text{ cm}^3 \tag{7}$$

Where  $N_{mp}$  is the metric count of pile warp yarn. As a result volume of ground warp yarns ( $V_g$ ) in the cuboid can be calculated as follows:

$$V_g = \frac{\text{No. of ground warp yarns per cm} \times 1 \text{ cm} \times Z \text{ cm} \times (1 + \frac{C_1}{100})}{N_{mg} \times \rho_{yg}}, \text{cm}^3 \tag{8}$$

Where

- $N_{mg}$  is the metric count of ground warp yarn
- $\rho_{yg}$  is the density of ground warp yarn g/cm<sup>3</sup>
- $C_1$  is the crimp of ground warp yarn %

Also volume of weft (filling) yarns ( $V_w$ ) in the cuboid can be calculated as follows :

$$V_w = \frac{\text{Picks/cm} \times z \times 1 \text{ cm} \times (1 + \frac{C_2}{100})}{N_{mf} \times 100 \times \rho_{yf}}, \text{cm}^3 \tag{9}$$

Where

- $N_{mf}$  is the metric count of weft (filling) yarns
- $\rho_{yf}$  is the density of weft (filling) yarns, g/cm<sup>3</sup>
- $C_2$  is the crimp of weft (filling) yarns %

\* **Yarn bulk density calculation:** Peirce [43] suggested that yarn bulk density ( $\rho_y$ ) can be calculated as follows:

$$\rho_y = \rho_f (1 - \epsilon_y) \text{ g/cm}^3 \tag{10}$$

Where  $\rho_f$  = fibre density for cotton (1.54), g/cm<sup>3</sup>

$\epsilon_y$  = yarn porosity.

Theoretical approaches were used in order to estimate the porosity of the yarn ( $\epsilon_y$ ) within the fabric using certain assumptions based on yarn and fibre parameters.

The yarn porosity ( $\epsilon_y$ ) defined as the ratio of the pore area to the yarn cross – section area can be calculated by Equation (11) [44].

$$\epsilon_y = 1 - \phi_y \tag{11}$$

Where  $\phi_y$  = packing density of yarn i.e. the ratio of the total fibres area to the yarn area.

The circular cross – sectional theoretical diameter of the fibre ( $d_f$ ) was calculated using Equation (12)

$$\text{Fibre tex} = \frac{\pi}{4} d_f^2 \times 10^5 \times \rho_f \tag{12}$$

Where  $d_f$  = fibre diameter cm

$\rho_f$  = fibre density g/cm<sup>3</sup>

In Equation (11) to calculate the inter – fibre yarn porosity theoretically the packing density of the yarn was calculated by using the ratio of total fibres area to the total yarn area. The theoretical circular yarn diameter ( $d_y$ ) was used to calculate the total yarn area ( $A_y$ ). The total fibres area was calculated using the number of fibres in the cross – section (n) and the area of one fibre ( $A_f$ ) assuming that the fibre diameters within the yarn cross – section were equal to an another.

The average number of fibres (n) in the cross – section of the yarn was found theoretically by using (equation 13).

$$n = \frac{N_{mf}}{N_{my}} = \frac{\text{yarn tex}}{\text{fibre tex}} = \frac{\text{yarn tex}}{\frac{\pi}{4} d_f^2 \times 10^5 \times \rho_f} \tag{13}$$

Also by using Equations (13, 14, 15) the packing density of the yarn ( $\phi_y$ ) can be calculated based on the theoretical fibre (n) the area of the one fibre ( $A_f$ ) whose cross – section was assumed to be circular and yarn area ( $A_y$ ).

$$\phi_y = \frac{n \times A_f}{A_y} = \frac{\text{yarn tex} \times \frac{\pi}{4} d_f^2}{\frac{\pi}{4} d_f^2 \times 10^5 \times \rho_f \times \frac{\pi}{4} d_y^2} \quad (14)$$

$$\phi_y = \frac{\text{yarn tex}}{10^5 \times \rho_f \times \pi d_y^2 / 4} \quad (15)$$

Where  $d_y$  = yarn diameter cm.

By assuming that the cross – section of the yarns are circular and the volume percentage of fibres is 60% [45] it is known that the level of twist the slope of the fibre and so on can influence this percentage so 60% is just a reasonable approximation. Thus yarn diameter can be obtained by the following equation:

$$d_y = 0.01189 \sqrt{\frac{\text{Den}}{\rho_f \times 0.6}} \text{ Mm} \quad (16)$$

In which  $d_y$  = yarn diameter in mm

Den = yarn denier and

$\rho_f$  = fibre bensity  $\text{g/cm}^3$

By this way the theoretical yarn bulk density ( $\rho_y$ ) was calculated by Equation (17) using Equations [1,2,6 and 7] based on the theoretical fibre number in the cross – section of the yarn (n) the theoretical fibre diameter ( $d_f$ ) and the theoretical yarn diameter ( $d_y$ ).

$$\rho_y = \frac{\text{yarn tex}}{10^5 \times \pi d_y^2 / 4} \text{ g/cm}^3 \quad (17)$$

Where  $d_y$  is yarn diameter in cm.

By substituting in Equations (8, 9) with the values of yarn bulk density ( $\rho_y$ ) the values of  $V_g$  and  $V_w$  can be calculated easily.

As a result total volume of yarns (pile ground and weft) in the cuboid can be calculated as follows:

$$V_{\text{total}} = V_p + V_g + V_w \text{ cm}^3 \quad (18)$$

Then from Equation (2.4 and 18) total overall porosity can be calculated as follows:

$$\text{Porosity } (\epsilon) = 1 - \frac{V_{\text{fibres}} (V_{\text{total}})}{\text{Volume of cuboid}(V_c)}$$

$$\text{Hence Porosity } (\epsilon) = 1 - \frac{(V_p + V_g + V_w)}{(n_s/n^2) \times t \times 1 \text{cm}} \quad (19)$$

In the design of a porous fabric for a particular application e.g terry woven fabric it is most likely that porosity ( $\epsilon$ ) and pile height (H) will be selected first. As a result  $\epsilon$  (fabric porosity) H (pile height)  $d_y$  (effective yarn diameter parameter) and n (number of yarns per fabric opening in warp and filling). As a result, H  $d_y$  and n have been selected as design constants. From these it is desired to predict the yarn size (Tex), and Fabric setting (ends and picks/cm) required to provide a fabric having the given pile height and porosity.

### Fabric Manufacture and Testing

In the experimental part of this study in order to compare the values of overall porosity calculated from theoretical modeling and that using experimental overall porosity six woven terry samples at different pile heights weft densities and weft linear densities were carried out.

The pile of the terry fabrics used in this research was constructed on both sides of the fabric as can be seen in Figure 1a.

Generally this structure consists of three components namely pile warp yarn ground warp yarn and weft yarn which from the terry woven fabric. The specifications of each fabric are summarized in Table 1. The pile and ground warp density was 24 ends/cm and the values of weft density range from 10 to 20 picks/cm.

The pile and ground warps were plied cotton yarns of 24/2 Ne whereas the values of weft counts range from 12/1 to 20/1 Ne and were made from cotton yarns. Pile loops were embedded using basic 3-pick terry toweling and manufactured with different pile heights.

Warps are ordered throughout the fabric width 2:2 piles and ground warps. In 2:2 warp order each two ground warp ends are followed by two pile warp ends. In Figure 2, the weave notation of 3 weft pile is given in 2:2 warp orders.

The cotton terry fabrics used in the experimental work were woven by Eng. Mahmoud Mohamed El-Fowaty, Chairman of the Board of Directors of (El-Fowaty Tex) Company in Aga Egypt.

For the experimental investigation of porosity and static water absorption different types of terry woven fabrics with constant set of warp and varying set of weft and varying yarn fineness and varying warp pile height were produced on PROMATECH Vamatex Leonardo Dyna Terry model Double Flexible Rapier 230 cm Terry Weaving m/c. with a Jacquard shedding mechanism using the Staublely – CX870.

Produced fabrics are intended to be used for face towel where water absorbency is a necessary product feature. The incorporation of these hydrophobic samples aims to verify the versatility of the test. These woven fabric samples (10 cm × 10 cm) were conditioned in the test environment (20+2°C and 65+2% relative humidity) for at least 24 hours before testing.

The experimental evaluation of the porosity was carried out by measuring the fabric weight, fabric thickness and by calculating the fabric bulk density from the length the width and the thickness of the terry woven fabrics.

The porosity of the fabric was determined according to Equation (20) with reference to Hsieh's work [45].

$$\text{Porosity}(\epsilon) = 1 - \frac{\text{Fabric weight}(\text{g/cm}^2)/\text{Fabric thickness}(\text{cm})}{\text{Bulk density of fiber}(\text{g/cm}^3)} \quad (20)$$

The static water absorption was measured according to method [46]. The samples were conditioned in laboratory conditions cut into pieces (10 cm × 10 cm) and then weighed (Md). After that the samples were kept for one minute in distilled water. After being removed from



Figure 2: The weave repeat of the terry fabric (Basic 3-pick terry weave in 2:2 warp order [42].

the water they were hung for three minutes to remove excess water and the weight of the wet samples ( $M_w$ ) was measured. An electronic balance was used in the weight measurements. The static water absorption ( $S_w$ ) was calculated using the following formula:

$$S_w = (M_w - M_d) / M_d \times 100 \% \quad (21)$$

Also, the static water absorption or (liquid retention capacity) as a function of experimental overall porosity ( $\epsilon$ ) distilled water density (0.997 g/cm<sup>3</sup>),  $\rho_w$  and fibre density ( $\rho_f$ ) can be given as [47].

$$S_i = \frac{\rho_w \left( \frac{\epsilon}{1 - \epsilon} \right)}{\rho_f} \quad (22)$$

The proposed mechanism by Hsieh of water absorption depends on pore size pore size distribution pore connectivity and total pore volume.

The fabric's thickness (t) and surface density (M) was measured in accordance with ISO 5084: 1996 [48] and LST ISO 3801:1998 [49] respectively. Fabric properties were given in Table 2.

## Results and Discussion

The results of overall porosity and static water absorption at different pile heights picks per cm and weft yarn counts are presented in tabulated form in Table 2. It could be seen from this table that the value of both overall porosity and static water absorption varies very rapidly from one variant to the other. In order to predict the overall porosity values for terry woven fabrics the values of pile loop length (L) and yarn density ( $\rho_y$ ) are calculated And from a knowledge of yarn weft count ( $N_{mf}$ ) picks per cm( $n_2$ ) yarns crimp ( $c_1, c_2$ ) and fabric thickness (t) the volume of pile yarns ( $V_p$ ) and volume of ground warp yarns ( $V_g$ ) and volume of weft yarns ( $V_w$ ) per unit volume (cuboid) as

a new developed equations were calculated and expressed in part of the theoretical model. From Equation (8) it could also be seen that the average overall porosity is affected by the pile height weft yarn diameter and picks spacing. Table 2 gives the calculated and experimental values of overall porosity.

When Table 1 was examined it was seen that fabric sample No. (3) has the smallest fabric weight weft density terry (pile) ratio weft diameter and number of piles per unit area. So it is possible that fabric No. (3) has the highest overall porosity through the interfibre volume of pile yarns ( $V_p$ ) ground warp yarns ( $V_g$ ) and weft yarns ( $V_w$ ). On the contrary, Sample No. (2) has the smallest overall porosity and static water absorption percentage. However in this study since the volume of air voids between the yarns and through the interstices in the fibres was calculated theoretical values of overall porosity were obtained very close to the experimental results as shown in Figure 3.

The match is close which is also indicated by the high values of correlation coefficients and  $R^2$  was obtained from the statistical analysis. Figure 4 shows the correlation plots between the predicted and measured values (X- axis – measured – values y- axis – predicted values). In Figure 4 the fabric overall porosity is compared with the corresponding fabric overall porosity calculated from the fitted Equation (19) to the different tested fabrics. The values of overall porosity were correlated well ( $R=0.9915$ ) with a slope of 1.325 and an intercept of 0.275.

Static water absorption in terry woven fabrics is related to overall porosity. As discussed earlier variability in overall porosity affected the static water absorption values. Also as demonstrated in Figure 5 there is a positive linear relationship between the predicted overall porosity and static water absorption. Thus the higher overall porosity the higher

Sample no	Fabric Weight g/m <sup>2</sup>	Fabric thickness at 10 g/cm <sup>2</sup> , mm	No of picks/cm	Weft yarn count				Pile * (terry) ratio	Pile ** height, mm	No of piles /cm <sup>2</sup> for each face	Yarn crimp	
				Ne	Nm	Tex	Den				Wrap c <sub>1</sub>	Wrap c <sub>2</sub>
1	337	12300	10	12	20.28	46.2	442.9	3.545	5.318	20	5.74	6.53
2	366	0.7629	20	12	20.28	46.2	442.9	2.645	1.984	42	8.03	7.92
3	266	11371	10	20	33.902	29.525	265.75	2.604	3.906	20	4.72	8.49
4	366	11897	15	12	20.28	49.2	442.9	4.253	4.253	30	5.14	6.48
5	299	12394	10	16	27.04	36.906	332.19	3.113	4.670	20	5.93	5.39
6	361	12434	15	16	27.04	36.906	332.19	3.545	3.545	20	5.88	5.71

\*Pile ratio= length of pile yarn/metre of towel [47].

$$** \text{ Pile height} = \left[ \frac{\text{pile ratio}}{\text{pick / cm}} \right] \times \frac{1}{2} \times \text{type of terry, cm}$$

Table 1: Fabric Specification of terry woven fabrics.

Sample No	Fabric thickness at 10 g/cm <sup>2</sup> , cm	No of picks/cm	volume of fabric cuboid cm <sup>3</sup>	Loop length of pile yarn metre x10 <sup>5</sup>	Weft yarn diametre, mm	Weft yarn bulk density, g/cm <sup>3</sup>	calculated, cm <sup>3</sup> x10 <sup>5</sup>				Overall porosity ( )		Static water absorption %	Liquid retention capacity SI
							V <sub>p</sub>	V <sub>g</sub>	V <sub>w</sub>	Total	Theoretical	Experimental		
							Eq.(7)	Eq.(8)	Eq.(9)	Eq.(18)	Eq.(19)	Eq.(20)		
1	0.13200	10	0.024600	2.34796	0.2603	0.924	1.80432	1.35429	1.13701	4.29562	0.82538	0.822	374.48	2.9897
2	0.07629	20	0.007629	1.25778	0.2603	0.924	0.96656	0.69181	1.15181	2.8107	0.63165	0.688	255.74	1.4276
3	0.11371	10	0.022742	2.30065	0.2016	0.9245	1.76796	1.34122	0.69404	3.80322	0.83277	0.848	374.06	3.6118
4	0.11897	15	0.015863	1.78694	0.2603	0.924	1.37320	0.89777	1.12574	3.39671	0.78587	0.800	345.58	2.5896
5	0.12394	10	0.024788	2.35289	0.2254	0.9249	1.80811	1.35672	0.84281	4.00764	0.83832	0.843	370.23	3.4762
6	0.12434	15	0.016579	1.82314	0.2254	0.9249	1.40101	0.90405	0.84537	3.15043	0.80997	0.811	379.78	2.7780

Table 2: Comparison of experimental result with the calculated values of overall porosity.

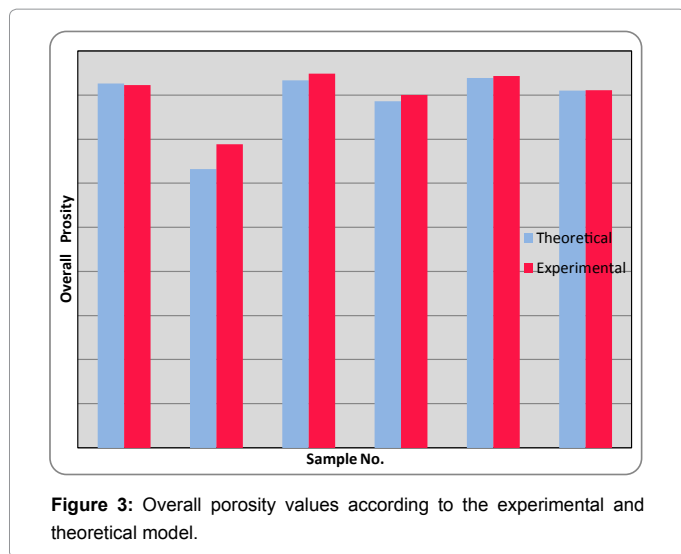


Figure 3: Overall porosity values according to the experimental and theoretical model.

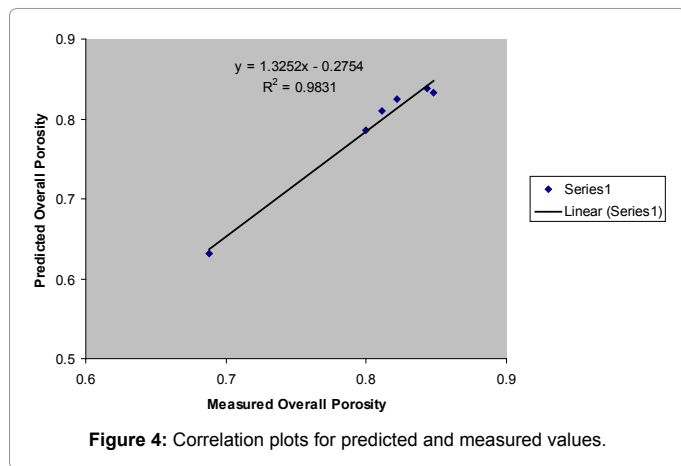


Figure 4: Correlation plots for predicted and measured values.

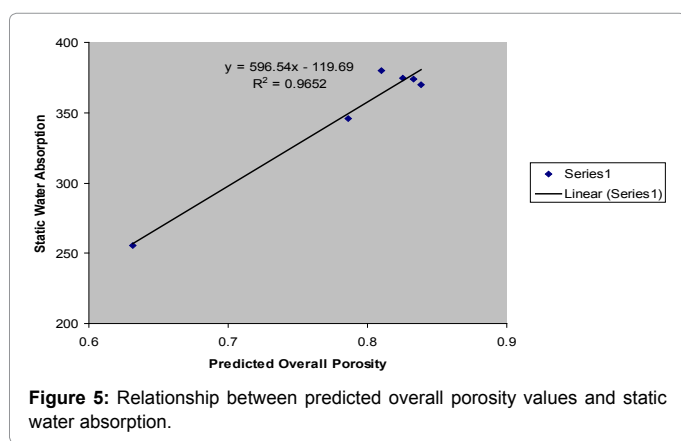


Figure 5: Relationship between predicted overall porosity values and static water absorption.

static water absorption.

Also the correlation between the calculated values of porosity obtained through the geometrical model and the experimental results of liquid retention capacity obtained through testing show high (R) value as shown in Figure 6. This indicates the functionality of the model for predicting the capillary flow of liquid through terry fabrics

in terms of fibre and yarn structure parameters. The results obtained through the theoretical model are somewhat overestimated compared the experimentally obtained results, which can be related to the approximation made to the yarn thickness (yarn diameter) based on an average diameter value. But in the theoretical approach the circular yarn diameter ( $d_y$ ) must be calculated using the major and minor diameter of the yarn at constancy yarn perimeter. Nevertheless the experimental and theoretical values are of the same ranking order.

## Conclusion

In the case of calculating the overall porosity of terry woven fabrics air voids volume between not only yarns but also fibres must be considered. Thus in this study air voids volume or volume of yarns and fibres within the fabric and yarns respectively constituting the yarn structure were calculated theoretically and it was tried to determine the overall porosity of terry woven fabrics.

Due to differences between ideal and real geometry and random variation of fabric structure there are not exactly dependences between experimental overall porosity and predicted overall porosity values. However closeness of the results of the predictions based on the calculated values from the theoretical model and experimental values show that our model can be used successfully for the prediction of overall porosity for different terry woven fabrics. This model is practically simple and efficient.

The overall porosity and static water absorption are strongly related to each other. If a fabric has very high porosity it can be assumed that it can absorb large amount of water and wet easily. Because it was found that nearly positive linear relationship exists between overall porosity and static water absorption values ( $R=0.9824$ ).

It could be assumed that this developed model (overall porosity) is applicable for predicting static water absorption of other woven types produced with different fibre types.

Before manufacturing theoretical model is aimed to establish and predict the value of overall porosity via static water absorption and some fabric properties.

The overall porosity was calculated for a geometrical model of terry woven fabric by means of knowing its geometrical parameters. The comparison between both calculated and measured values was then possible. The good agreement shown by Table 2 and Figure 4 supports the validity of the derived Equation (11) at least within the range of

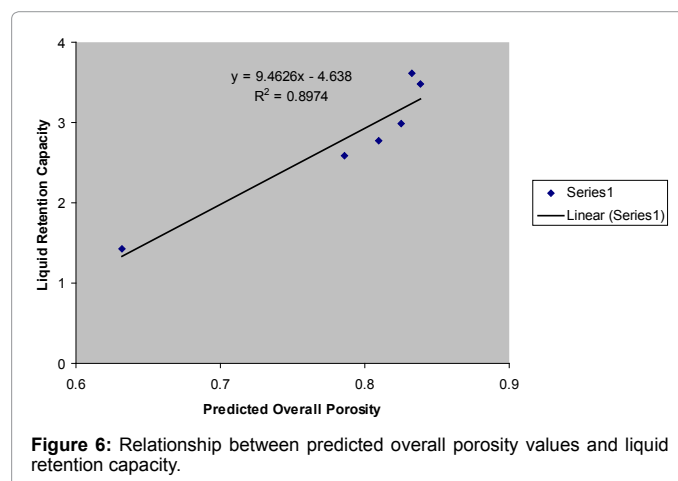


Figure 6: Relationship between predicted overall porosity values and liquid retention capacity.

fabric specification used. From such study a good prediction of fabric overall porosity could be calculated with Knowledge of fabric thickness yarn count warp and weft spacing and pile height.

#### Acknowledgement

We would like to acknowledge Eng. Mahmoud Mohamed El-Fowaty Chairman of the Board of Directors of (El-Fowaty Tex) Company in Aga Egypt for his assistance in manufacturing and supplying the terry woven fabrics used in the experiments.

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