The influence of Hollow Fibers 'Ratio Variation on Some Fabrics' Comfort Properties

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Abstract: Development of smarteh synthetic fibers spinning led to produce smart fabrics reacts with human body variables in different sittings and different weathers, which affects man as the reaction occurs between the fabrics and human body and the surrounding environment, so these textiles are called functional textiles that are used in production of comfortable clothes that suits the exerted effort and dynamic energy of the person who wears these clothes. So this study aims to produce fabrics characterized by required comfort properties, by production of 60 woven samples using polyester hollow fibers and cotton materials and blend both of them with different percentages, and also the fabrics production is performed under the study in different densities for wefts in measuring unit, that are (16, 18, 20 and 22) weft/cm, also it's produced with different weave structures that are: plain weave 1/1, twill weave 2/1, twill weave 2/2, and twill weave 3/1. Then some tests are done on all produced fabrics, these tests are: air permeability, water absorption, elongation, and the thickness, in addition to weight per square meter. Then tabulation of tests' results and performing statistical analysis for it and also drawing its specific chart relations.

[Saadia O. K. Ibrahim and Gihan M. T. Genedy. **The influence of Hollow Fibers 'Ratio Variation on Some Fabrics' Comfort Properties.** Journal of American Science 2012; 8(3):288-297]. (ISSN: 1545-1003). http://www.americanscience.org. 38

Key word: Warp (end): Vertical yarns; **Weft (Pick)**: Horizontal yarns; **yarn Count**: thickness of Yarn; **Picking device**: The Method Which Used To Pass Wefts; **Weft Set**: Number of weft yarns per Cm

1. Introduction

Clothes using comfort is considered a significant sense that is realized by the personal sense, and comfort is defined as non feeling with pain when wearing the clothes [1] .

And when discussing the comfort factor the relations between different types of clothes and the person characteristics who wears them and also the environment characteristics, should be considered, consequently the comfort is divided into several types:

Sensorial comfort

This type of comfort is associated with the extent to which the man feels with comfort when the clothing touches his skin, also it should be noticed that there are unpleasant senses that causes uncomfortable such as itching, inflammation, roughness, warmth and coldness [2] .

Body movement comfort

This type of comfort concerns with free movement and decreasing the burden or load on the body and keeping the body shape fitness, as the persons should move freely inside the clothes they wear, and when the clothes hinder the persons' movement the increasing burden and the pressure result on the body causing non comfort, and there are conditions to achieve the body movement comfort, these conditions are represented in:

Flexibility:

The clothes fabric should be characterized with flexibility, as when the man moves his skin expands and shrinks with the body movement [2].

Elongation:

The fabrics' elongation shouldn't be less than 15%, and the **fabric** of elongation value is less than 15% is considered of the harsh fabric [2]

Weight:

The fabric's weight participates in feeling with comfort or not, as the clothing's weight depends upon the amount of the fibers producing the clothing and also the size and the weight of the fabrics from which the clothing is made, so it should be considered that the clothing weight shouldn't exceed 3.8 kgm for men, while for women their clothing weight shouldn't exceed 2.3kgm [2] .

Thermo physiological comfort:

The most important required properties of the clothing are the physiological properties and contact characteristics with the body i.e. touching sense, and of the necessary requirements for these clothing the balance between the thermal control and controlling the moisture transfer from the body, meaning that the clothing must allow getting rid of both heat and moisture by the same rate they are generated, it's known that getting rid of body moisture occurs by both of respiratory system and body surface, to reach to the condition in which the clothing provide keeping the body dry and not wet as far as possible [1,3] .

And there are some properties that affect the thermo physiological comfort, and of these properties are:

Moisture absorption:

Water absorption property is considered one of the factors by which the most suitable textile fibers can be determined where comfort suitability, as there is a direct relation with the fabrics ability to absorb the moisture, maintaining it and emitting by capillarity.

Air permeability:

Fabrics' air permeability is considered of the important properties of the clothing that plays an important role in determining the suitability extent of these clothing for use, also it affects the warmth characteristic that the clothing should be characterized with specially those used during cold weather [4].

Thermal insulation:

Moisture management characteristics and its transfer through the textile materials participates in determination of comfort sense of the clothing made from [5] . the lower adhesion area between the skin and the clothing the more comfort sense, so recently it was directed to produce synthetic fibers of different cross section than the regular circular section that increases the fibers friction with the skin and gives with non comfort. And this is to obtain the lowest adhesion area, at the same time we obtain the required luster and smoothness [6-8] .

It is worth mentioning that the hollow fibers are characterized that they of lighter weight and larger surface area that allows rapid vaporization and rapid removal of the moisture from the skin to the cloth surface that can vaporizes it fast, also it warms the body[9] .

Also the hollow fibers are characterized with some other properties such as smoothness and comfort, and non wore out by friction, in addition to shrinkage resistance, wrinkling and color fading, also they are characterized by the ability of washing and rapid drying [10,11] .

Also the made hollow fibers from polyester work to protect against the ultraviolet rays, as protecting substances are put inside the central space of these fibers, the polyester fibers are treated with vinyl ethylene alcohol, and achieves protection percentage against ultraviolet rays reaches 90% [12] .

2. The Experimental Work:

Two kinds of textile materials were used in this research: polyester hollow fibers and cotton and difference in blending ratio between them.

Table (1): The specifications of machine used for produced all samples

No.	Property	Specification
1	Kind of loom	Dobby
2	Number of loom healds	16 healds
3	Speed of machine	280 picks per minute
4	Picking device	Rigid Rapier
5	Kind of shading	Open shade
6	Width of loom	200 cm
7	Take up motion	Positive
8	Lett off motion	Positive

Table (2):The specifications of warps used for produced all samples

Warp specifications / Kind of material	The first warp				The second warp				The third warp				The fourth warp			
	100% polyester hollow fibers				67% polyester hollow fibers, 33% cotton				50% polyester hollow fibers, 50% cotton				33% polyester hollow fibers, 67% cotton			
	Arrangement of ends		Arrangement of wefts		Arrangement of ends		Arrangement of wefts		Arrangement of ends		Arrangement of wefts		Arrangement of ends		Arrangement of wefts	
Polyester hollow fibers	100%		100%		2		2		1		1		1		1	
Cotton	-		-			1		1		1		1		2		2

Table (3):The specifications of produced samples

No.	Property	Specification
1	Kind and count of ends	Polyester hollow fibers 162 × 2 denier, cotton 32/2(S).
2	Kind and count of wefts	Polyester hollow fibers 162 × 2 denier, cotton 32/2(S).
3	Reed used (dents per cm)	8 dents per cm
4	Reeding (sleying)	4 ends/dent
5	Number of ends/cm (warp set)	32 yarns per cm
6	Number of wefts/cm (weft set)	16, 18, 20 and 22 picks/cm
7	Number of healds used	12 healds + 2 for selvges
8	Drafting system	Directly (on line)
9	Width of reed	150 cm
10	Weave structures	Plain (1/1), twill (2/1), twill (2/2) and twill (3/1)

Tests and analysis:

In this part several tests were carried out in order to evaluate the produced fabrics, these tests were:

The air permeability of fabrics was determined according to the (A. S. T. M) ([13]).

The fabric elongation was determined according to the (A. S. T. M. – D79 -99) [14].

The fabric thickness was determined according to the (A. S. T. M. – D1777-84)[15] .

The fabric weight was determined according to the (A. S. T. M. – D1910-64)[16] .

The water absorption of fabrics was determined according to the (A. S. T. M. – D4491).

3. and Discussion:

Results of experimental examination on the produced samples are presented in the following tables (4-7) and graphs. Results were statically analyzed for data listed.

Table (4):The results of the tests applied to the samples which produced from 100% polyester hollow fibers

Fabric specifications / Fabric properties		Air permeability ($cm^3/cm^2/s$)	Water absorption (%)	Elongation (%)		Thickness (mm)	Weight per square meter (gm)
Weave structure	Weft set			warp	weft		
Plain weave (1/1)	16	11.37	121.20	25.75	18.50	0.405	190.51
	18	7.36	99.40	28.00	19.80	0.410	206.40
	20	4.85	81.20	31.25	20.50	0.419	212.09
Twill weave (2/1)	16	58.97	125.38	21.25	19.25	0.415	186.58
	18	49.23	105.34	21.50	19.30	0.420	192.05
	20	38.17	96.40	26.50	21.10	0.425	204.47
	22	33.87	76.60	28.00	27.00	0.432	211.34
Twill weave (2/2)	16	58.03	125.43	21.25	22.50	0.420	181.61
	18	47.17	117.66	21.25	23.40	0.422	190.40
	20	40.83	102.60	22.00	24.10	0.425	199.50
	22	32.87	97.68	24.50	24.50	0.430	209.11
Twill weave (3/1)	16	64.33	130.50	18.50	20.80	0.440	180.30
	18	50.33	121.60	19.80	21.30	0.442	190.34
	20	44.20	118.50	22.00	23.00	0.450	196.70
	22	40.80	107.88	23.50	26.50	0.453	208.77

Table (5):The results of the tests applied to the samples which produced from 67% polyester hollow fibers and 33% cotton fibers

Fabric specifications / Fabric properties		Air permeability ($cm^3/cm^2/s$)	Water absorption (%)	Elongation (%)		Thickness (mm)	Weight per square meter (gm)
Weave structure	Weft set			warp	weft		
Plain weave (1/1)	16	9.14	197.50	20.00	7.10	0.420	195.55
	18	5.41	150.00	23.50	7.65	0.423	207.73
	20	3.61	110.90	25.50	7.65	0.428	217.46
Twill weave (2/1)	16	39.73	204.80	17.00	7.10	0.450	186.75
	18	32.67	182.70	19.00	9.50	0.455	197.45
	20	25.30	160.20	22.00	9.90	0.460	211.90
	22	18.83	145.60	22.50	8.75	0.462	220.40
Twill weave (2/2)	16	46.07	212.07	15.00	7.30	0.460	182.76
	18	34.97	191.70	15.40	8.00	0.465	192.57
	20	24.10	185.30	17.00	8.30	0.482	207.59
	22	18.43	160.12	18.30	8.75	0.495	218.43
Twill weave (3/1)	16	48.80	218.40	14.00	8.25	0.470	182.44
	18	38.03	197.00	15.25	9.00	0.478	192.00
	20	28.77	190.60	17.25	7.13	0.485	205.84
	22	23.33	164.25	19.40	7.90	0.500	211.06

Table (6):The results of the tests applied to the samples which produced from 50% polyester hollow fibers and 50% cotton fibers

Fabric specifications / Fabric properties: Weave structure	Weft set	Air permeability ($cm^3/cm^2/s$)	Water absorption (%)	Elongation (%) warp	Elongation (%) weft	Thickness (mm)	Weight per square meter (gm)
Plain weave (1/1)	16	7.01	200.00	18.75	8.10	0.432	194.66
	18	4.40	170.00	21.25	8.40	0.435	208.48
	20	2.80	143.00	23.90	8.50	0.440	220.90
Twill weave (2/1)	16	32.70	230.00	16.30	8.90	0.470	193.27
	18	26.07	195.00	16.75	9.16	0.473	204.85
	20	20.63	187.70	18.60	8.75	0.480	212.43
	22	15.00	155.80	20.10	8.50	0.484	221.69
Twill weave (2/2)	16	39.40	236.00	13.00	8.40	0.490	190.73
	18	30.13	220.00	15.60	8.40	0.495	195.88
	20	21.67	200.00	17.50	8.16	0.502	208.38
	22	15.57	182.70	17.50	8.25	0.505	218.21
Twill weave (3/1)	16	43.63	246.00	14.20	8.25	0.510	189.86
	18	33.40	232.00	16.25	7.65	0.513	196.30
	20	28.13	214.50	16.70	8.00	0.520	208.00
	22	21.67	210.70	17.50	8.08	0.522	220.00

Table (7):The results of the tests applied to the samples which produced from 33% polyester hollow fibers and 67% cotton fibers

Fabric specifications / Fabric properties: Weave structure	Weft set	Air permeability ($cm^3/cm^2/s$)	Water absorption (%)	Elongation (%) warp	Elongation (%) weft	Thickness (mm)	Weight per square meter (gm)
Plain weave (1/1)	16	5.61	220.00	20.30	7.60	0.450	197.73
	18	5.41	187.30	23.40	8.00	0.454	210.30
	20	3.01	150.70	25.75	8.25	0.458	221.42
Twill weave (2/1)	16	32.60	242.00	17.00	7.25	0.505	195.51
	18	25.20	210.20	18.00	7.75	0.512	205.52
	20	17.10	197.50	19.50	8.00	0.518	213.40
	22	12.03	185.70	21.00	8.30	0.520	225.69
Twill weave (2/2)	16	40.50	250.45	12.90	7.10	0.522	192.41
	18	27.60	234.80	15.75	7.30	0.525	197.40
	20	21.73	219.40	15.90	8.50	0.528	211.46
	22	15.90	203.00	16.25	8.90	0.535	220.79
Twill weave (3/1)	16	38.63	257.00	13.00	8.00	0.532	190.89
	18	29.20	240.80	16.25	8.90	0.540	199.30
	20	21.70	223.70	16.60	9.22	0.550	210.70
	22	17.47	215.50	21.00	9.25	0.562	220.00

Air permeability:

The tables (4-7) show that, the increase of polyester hollow fibers percentage in the produced fabrics increases the cloth's ability for air permeability (all other executional specifications are constant).

This belongs to containing of the hollow fibers still air inside the fibers' center, this air gets out through the existed surface pores on the fibers' surface, in addition to the air that gets through the aerial gabs existed between warps and wefts for each weave structure.

On the other hand, we see that the cotton material characterizes by convolutions and also hairness that decreases the porous percentage between yarns' intersections that decreases the air permeability of the fabrics.

Table (8): Multi regression equation for the effect of number of picks per cm (X) and hollow fibers ratio (Y) on air permeability (Z) for all weave structures.

Weave structure	Multi regression equation
Plain (1/1)	$Z = 31.8764 - 2.8066\,X + 0.2538\,Y + 0.07\,X^2 + 0.0004\,Y^2 - 0.0143\,XY$
Twill (2/1)	$Z = 125.0377 - 8.1456\,X + 0.0902\,Y + 0.1463\,X^2 + 0.0042\,Y^2 - 0.0155\,XY$
Twill (2/2)	$Z = 211.6459 - 15.0371\,X - 0.2729\,Y + 0.2902\,X^2 + 0.0045\,Y^2 - 0.0029\,XY$
Twill (3/1)	$Z = 229.0951 - 18.2352\,X + 0.0832\,Y + 0.3891\,X^2 + 0.0027\,Y^2 - 0.0057\,XY$

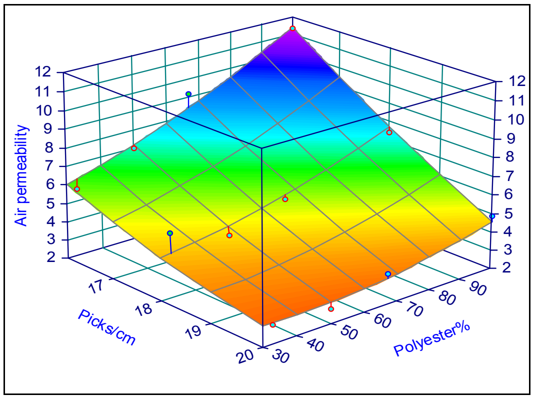

Fig (1): The effect of number of picks/cm and hollow fibers ratio on air permeability for produced samples for plain weave 1/1.

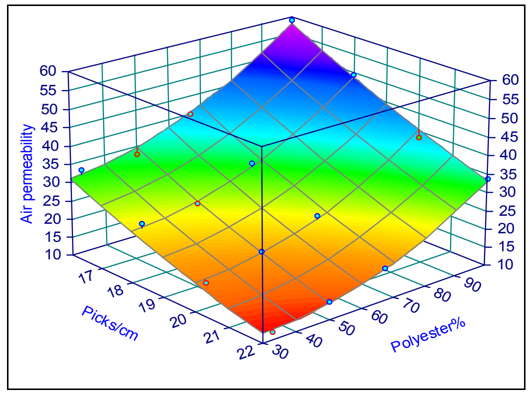

Fig (2): The effect of number of picks/cm and hollow fibers ratio on air permeability for produced samples for twill weave 2/1.

Water absorption:

The specific tables of tests results show that, Increasing the polyester hollow fibers' ratio in fabrics', water absorption decreases (all other executional specifications are constant), and this explains the ability of the cotton material to absorb water with larger percentage than polyester material.

Table (9): Multi regression equation for the effect of number of picks per cm (X) and hollow fibers ratio (Y) on water absorption percentage (Z) for all weave structures.

Weave structure	Multi regression equation
Plain (1/1)	$Z = 694.3828 - 33.8173\,X - 1.7037\,Y + 0.3469\,X^2 - 0.0087\,Y^2 + 0.0884\,XY$
Twill (2/1)	$Z = 598.4426 - 29.8177\,X - 0.0687\,Y + 0.4819\,X^2 - 0.0159\,Y^2 + 0.0307\,XY$
Twill (2/2)	$Z = 409.0392 - 8.2633\,X - 0.5036\,Y - 0.0627\,X^2 - 0.0164\,Y^2 + 0.0507\,XY$
Twill (3/1)	$Z = 475.9623 - 16.0847\,X - 0.3254\,Y + 0.1802\,X^2 - 0.0174\,Y^2 + 0.0469\,XY$

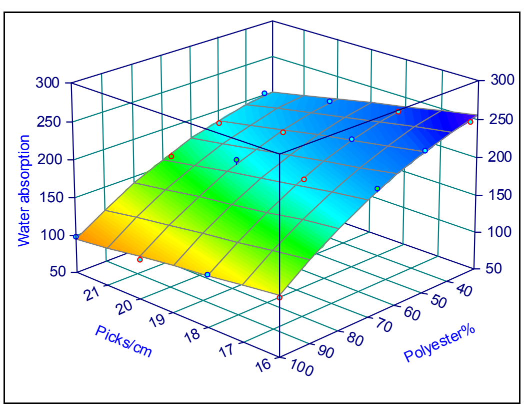

Fig (3): The effect of number of picks/cm and hollow fibers ratio on water absorption for produced samples for twill weave 2/2.

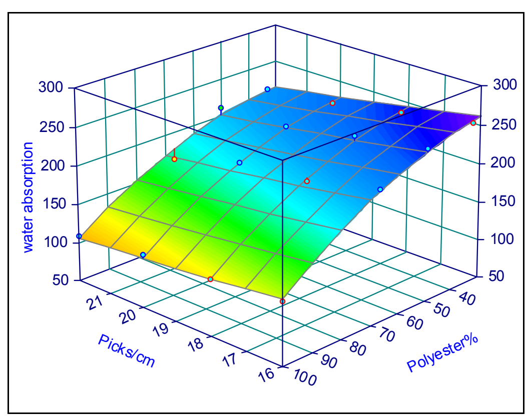

Fig (4): The effect of number of picks/cm and hollow fibers ratio on water absorption for produced samples for twill weave 3/1.

Elongation on the warp direction:

The tables (4-7) show that, With increasing the hollow fibers' percentage in the produced fabrics, the elongation percentage increases on the warp direction (all other executional specifications are constant), and this belongs to the characterization of the polyester fibers by high tensile strength in comparison to the tensile strength than cotton, that delays the cutting of polyester yarns inside the fabrics, so the elongation percentage increases.

Table (10): Multi regression equation for the effect of number of picks per cm (X) and hollow fibers ratio (Y) on elongation percentage (Z) on the warp direction for all weave structures.

Weave structure	Multi regression equation
Plain (1/1)	$Z= -5.1286 + 2.5502 X - 0.3048 Y - 0.0344 X^2 + 0.0028 Y^2 + 0.0006 XY$
Twill (2/1)	$Z= 23.1363 - 0.4778 X - 0.3264 Y + 0.0203 X^2 + 0.0017 Y^2 + 0.0096 XY$
Twill (2/2)	$Z= -3.7792 +1.6654 X - 0.1277 Y - 0.0266 X^2 + 0.0019 Y^2 - 0.0010 XY$
Twill (3/1)	$Z= 7.5043 + 0.4364 X - 0.1658 Y + 0.0156 X^2 + 0.0021 Y^2 - 0.0025 XY$

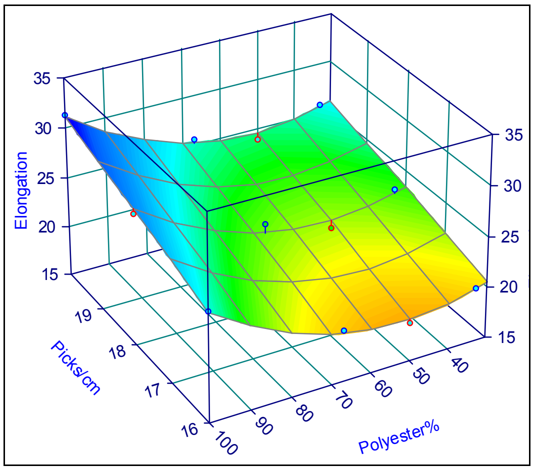

Fig (5): The effect of number of picks/cm and hollow fibers ratio on elongation on the warp direction for plain weave 1/1.

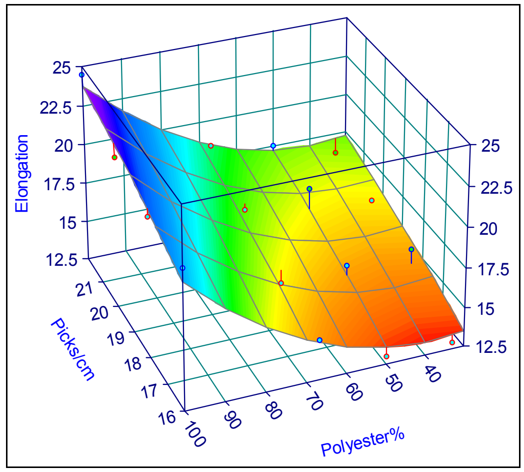

Fig (6): The effect of number of picks/cm and hollow fibers ratio on elongation on the warp direction for twill weave 2/2.

Elongation on the weft direction:

specific tables of tests results show that, With increasing the hollow fibers' percentage in the produced fabrics, the elongation percentage increases on the warp direction (all other executional specifications are constant), and this belongs to the characterization of the polyester fibers by high tensile strength in comparison to the tensile strength than cotton, that delays the cutting of polyester yarns inside the fabrics, so the elongation percentage increases.

Table (11):Multi regression equation for the effect of number of picks per cm (X) and hollow fibers ratio (Y) on elongation percentage (Z) on the weft direction for all weave structures.

Weave structure	Multi regression equation
Plain (1/1)	$Z= 6.3636 + 1.5730 X - 0.5922 Y - 0.0469 X^2 + 0.0050 Y^2 +0.0054 XY$
Twill (2/1)	$Z= 39.8330 - 1.6669 X - 0.7694 Y + 0.0248 X^2 + 0.0047 Y^2 + 0.0180 XY$
Twill (2/2)	$Z= 16.9719 + 0.3792 X - 0.6352 Y - 0.0072 X^2 + 0.0062 Y^2 + 0.0018 XY$
Twill (3/1)	$Z= 48.9542 - 2.1639 X - 0.8874 Y + 0.0442 X^2 + 0.0065 Y^2 + 0.0117 XY$

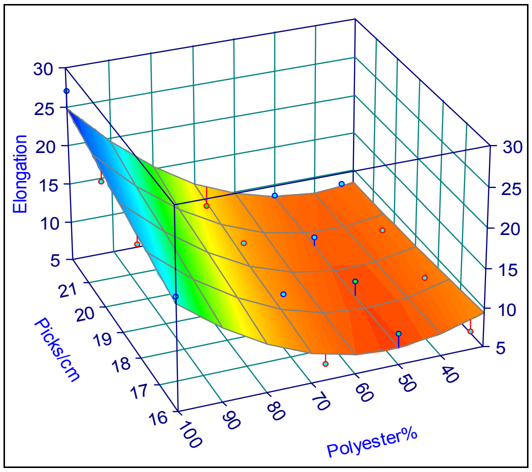

Fig (7):The effect of number of picks/cm and hollow fibers ratio on elongation on the weft direction for twill weave 2/1.

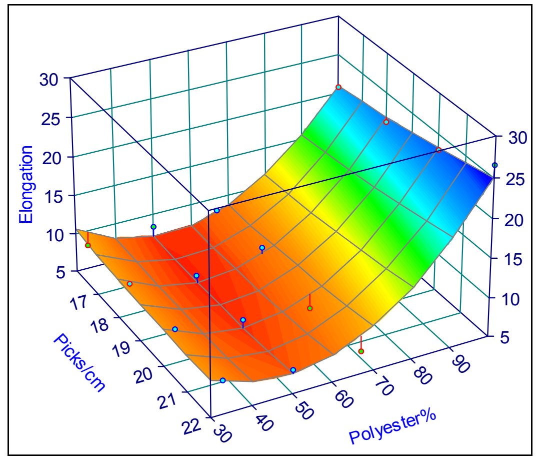

Fig (8):The effect of number of picks/cm and hollow fibers ratio on elongation on the weft direction for twill weave 3/1.

Thickness

It was shown from the tables (4-7) presence of an inverse relationship between the hollow fibers' percentage in the fabric and the thickness (all other executional specifications are constant), this belongs to the containing of the hollow fibers the central space that decreases the yarns' thickness, and consequently decreases the thickness of the produced fabric.

Table (12): Multi regression equation for the effect of number of picks per cm (X) and hollow fibers ratio (Y) on fabric thickness (Z) on the weft direction for all weave structures.

Weave structure	Multi regression equation
Plain (1/1)	$Z= 0.5646 – 0.0081 X – 0.0021 Y + 0.0003 X^2 + 0.00001 Y^2 + 0.00002 XY$
Twill (2/1)	$Z= 0.5242 + 0.0052 X – 0.0029 Y – 0.0001 X^2 + 0.00001 Y^2 + 0.000003 XY$
Twill (2/2)	$Z= 0.5905 – 0.0045 X – 0.0016 Y + 0.0002 X^2 + 0.000001 Y^2 – 0.000002 XY$
Twill (3/1)	$Z= 0.5892 – 0.0013 X – 0.0022 Y + 0.0002 X^2 + 0.00001 Y^2 –0.00002 XY$

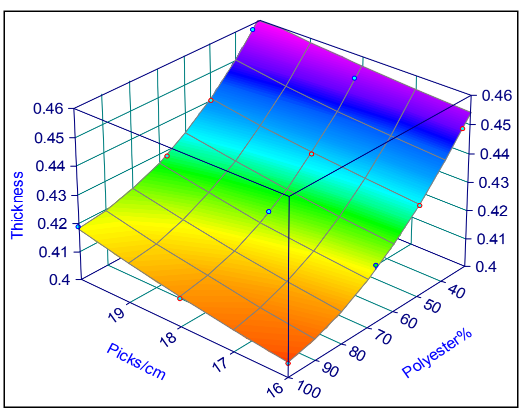

Fig (9):The effect of number of picks/cm and hollow fibers ratio on fabric thickness for plain weave 1/1.

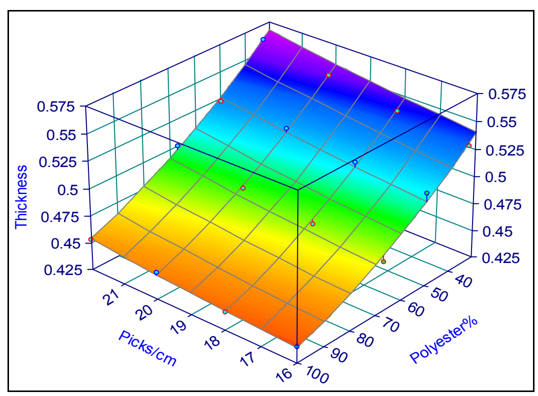

Fig (10):The effect of number of picks/cm and hollow fibers ratio on fabric thickness for twill weave 3/1.

Weight per square meter:

The specific tables of tests results show that, increase the weight per square meter of the produced fabrics with decrease of the polyester hollow fibers (all other executional specifications are constant).

As the cotton is considered of more textile fibers weight, as the specific density of the cotton material is 1.52 gm/cm^3, while the specific density of the polyester material is 1.38 gm/cm^3. This in addition the polyester material is hollow, that gives lighter weight.

Table (13): Multi regression equation for the effect of number of picks per cm (X) and hollow fibers ratio (Y) on weight per m^2 (Z) on the weft direction for all weave structures.

Weave structure	Multi regression equation
Plain (1/1)	$Z= -62.4885 + 24.0343 X + 0.1629 Y - 0.4844 X^2 - 0.0003 Y^2 - 0.0121 XY$
Twill (2/1)	$Z= 110.0449 + 5.7895 X - 0.0299 Y - 0.0131 X^2 - 0.0002 Y^2 - 0.0060 XY$
Twill (2/2)	$Z= 170.6216 - 1.1926 X - 0.0812 Y + 0.1698 X^2 - 0.0002 Y^2 - 0.0026 XY$
Twill (3/1)	$Z= 136.5839 + 2.8268 X - 0.1567 Y + 0.0647 X^2 + 0.0007 Y^2 - 0.0061 XY$

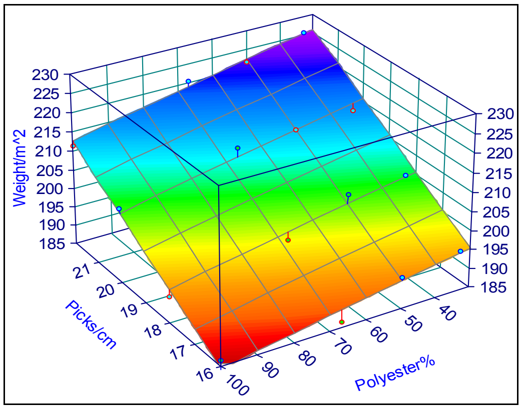

Fig (11): The effect of number of picks/cm and hollow fibers ratio on weight per m^2 for twill weave 2/1.

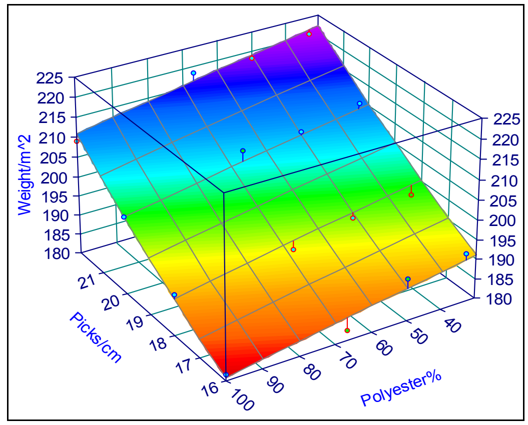

Fig (12): The effect of number of picks/cm and hollow fibers ratio on weight per m^2 for twill weave 2/2.

Table (14): The quality of functional properties percentages for samples produced under study as well as arranged in accordance with these quality.

Hollow fibers ratio	Weave structure	Picks / cm	Air permeability (+) $\frac{\sigma_i \times 10^2}{\sigma_{max}}$	Water absorption (+) $\frac{\sigma_i \times 10^2}{\sigma_{max}}$	Elongation (+) $\frac{\sigma_i \times 10^2}{\sigma_{max}}$ Warp	Elongation Weft	Thickness (-) $\frac{\sigma_{min} \times 10^2}{\sigma_i}$	Weight / m^2 (-) $\frac{\sigma_{min} \times 10^2}{\sigma_i}$	The sum	Arrangement
100% polyester hollow fibers	Plane weave 1/1	16	17.67	47.16	82.40	68.52	100.00	94.64	410.39	16
		18	11.44	38.68	89.60	73.33	98.78	87.35	399.18	22
		20	7.54	31.60	100.00	75.93	96.66	84.81	396.54	25
	Twill weave 2/1	16	91.67	48.79	68.00	71.30	97.59	91.72	469.07	3
		18	76.53	40.99	68.80	71.48	96.43	90.58	444.81	10
		20	59.33	37.51	84.80	78.15	95.29	88.18	443.26	11
		22	52.65	29.81	89.60	100.00	93.75	85.31	451.12	8
	Twill weave 2/2	16	90.21	48.81	68.00	84.81	96.43	99.28	487.54	1
		18	73.33	45.78	68.00	86.67	95.97	94.70	464.45	4
		20	63.47	39.92	70.40	89.26	95.29	90.20	448.54	9
		22	51.10	38.01	78.40	90.74	94.19	86.22	438.66	12
	Twill weave 3/1	16	100.00	50.78	59.20	77.03	92.05	100.00	479.06	2
		18	78.24	47.32	63.36	78.89	91.63	94.73	454.10	6
		20	68.71	46.11	70.40	85.19	90.00	91.66	452.07	7
		22	63.42	41.98	75.20	98.15	89.40	86.36	454.51	5
67% polyester hollow fibers and 33% cotton fibers	Plane weave 1/1	16	14.21	76.85	64.00	26.30	96.43	92.20	369.99	37
		18	8.41	58.37	75.20	28.33	95.74	86.80	352.85	51
		20	5.61	43.15	81.60	28.33	94.63	82.91	336.23	60
	Twill weave 2/1	16	61.76	79.69	54.40	26.30	90.00	96.55	408.70	17
		18	50.79	71.09	60.80	35.19	89.01	91.31	398.19	24
		20	39.33	62.33	70.40	36.67	88.04	85.09	381.86	31
		22	29.27	56.65	72.00	32.41	87.66	81.81	359.80	48
	Twill weave 2/2	16	71.62	82.52	48.00	27.04	88.04	98.65	415.87	14
		18	54.36	74.59	49.28	29.63	87.10	93.63	388.59	29
		20	37.46	72.10	54.40	30.74	84.02	88.85	365.57	42
		22	28.65	62.30	58.56	32.41	81.82	82.54	346.28	54

Hollow fibers' ratio	Weave structure	Picks / cm	Air permeability (+) $\frac{\sigma_i \times 10^2}{\sigma_{max}}$	Water absorption (+) $\frac{\sigma_i \times 10^2}{\sigma_{max}}$	Elongation (+) $\frac{\sigma_i \times 10^2}{\sigma_{max}}$ Warp	Elongation (+) Weft	Thickness (-) $\frac{\sigma_{min} \times 10^2}{\sigma_i}$	Weight / m² (-) $\frac{\sigma_{min} \times 10^2}{\sigma_i}$	The sum	Arrangement
	Twill weave 3/1	16	75.86	84.98	44.80	30.56	86.17	98.83	421.20	13
		18	59.12	76.65	48.80	33.33	84.73	93.91	396.54	26
		20	44.72	74.16	55.20	26.41	83.51	87.59	371.59	36
		22	36.27	63.91	62.08	29.26	81.00	85.43	357.95	50
50% polyester hollow fibers and 50% cotton fibers	Plane weave 1/1	16	10.90	77.82	60.00	30.00	93.75	92.62	365.09	43
		18	6.84	66.15	68.00	31.11	93.10	86.48	351.68	52
		20	4.35	55.64	76.48	31.48	92.05	81.62	341.62	59
	Twill weave 2/1	16	50.83	89.49	52.16	32.96	86.17	93.29	404.90	18
		18	40.53	75.88	53.60	33.93	85.62	88.02	377.58	33
		20	32.07	73.04	59.52	32.41	84.38	84.88	366.30	41
		22	23.32	60.62	64.32	31.48	83.68	81.33	344.75	57
	Twill weave 2/2	16	61.25	91.83	41.60	31.11	82.65	94.53	402.97	19
		18	46.84	85.60	49.92	31.11	81.82	92.05	387.34	30
		20	33.69	77.82	56.00	30.22	80.78	86.52	365.03	44
		22	24.20	71.09	56.00	30.56	80.20	82.63	344.68	58
	Twill weave 3/1	16	67.82	95.72	45.44	30.56	79.41	94.96	413.91	15
		18	51.92	90.27	52.00	28.33	78.95	91.85	393.32	27
		20	43.73	83.46	53.44	29.63	77.88	86.68	374.82	34
		22	33.69	81.71	56.00	29.93	77.59	81.95	360.87	46
33% polyester hollow fibers and 67% cotton fibers	Plane weave 1/1	16	8.72	85.60	64.96	28.15	90.00	91.18	368.61	38
		18	8.41	72.88	74.88	29.63	89.21	85.73	360.74	47
		20	4.68	58.64	82.40	30.56	88.43	81.43	346.14	55
	Twill weave 2/1	16	50.68	94.16	54.40	26.85	80.20	92.22	398.51	23
		18	39.17	81.79	57.60	28.70	79.10	87.73	374.09	35
		20	26.58	76.85	62.40	29.63	78.19	84.49	358.14	49
		22	18.70	72.26	67.20	30.74	77.88	80.07	346.85	53
	Twill weave 2/2	16	62.96	97.45	41.28	26.30	77.59	93.71	399.29	21
		18	42.90	91.36	50.40	27.04	77.14	91.34	380.18	32
		20	33.78	85.27	50.88	31.48	76.70	85.26	363.47	45
		22	24.72	78.99	52.00	32.96	75.70	81.66	346.03	56
	Twill weave 3/1	16	60.05	100.00	41.60	29.63	76.13	94.45	401.86	20
		18	45.39	93.70	52.00	32.96	75.00	90.47	389.52	28
		20	33.73	87.04	53.12	34.14	73.64	85.57	367.24	39
		22	27.16	83.85	67.20	34.26	72.06	81.95	366.48	40

Where: σ_i : value spread sheet $\sigma_{\min}$: the smallest value spread sheet $\sigma_{\max}$: the greatest value spread sheet

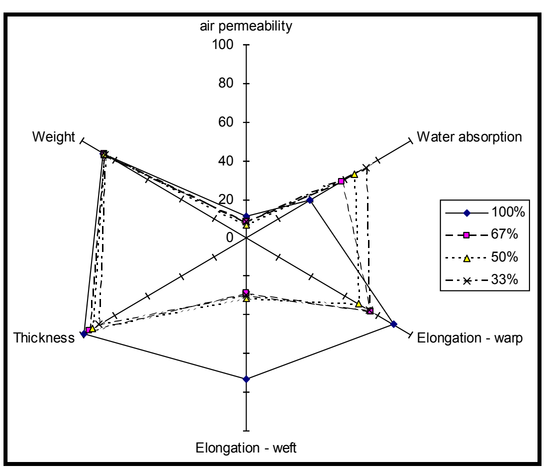

Fig. (13):Radar chart for samples which produced from plain weave structure 1/1 and 18 picks/cm

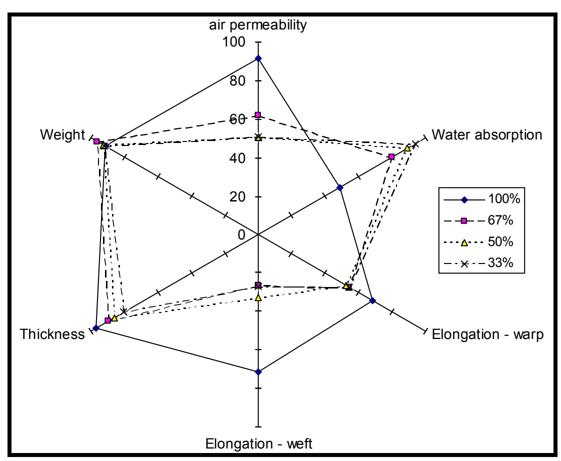

Fig. (14):Radar chart for samples which produced from twill weave structure 2/1 and 16 picks/cm

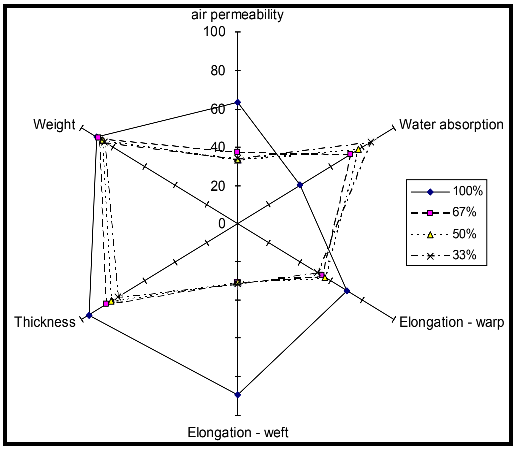

Fig. (15):Radar chart for samples which produced from twill weave structure 2/2 and 20 picks/cm

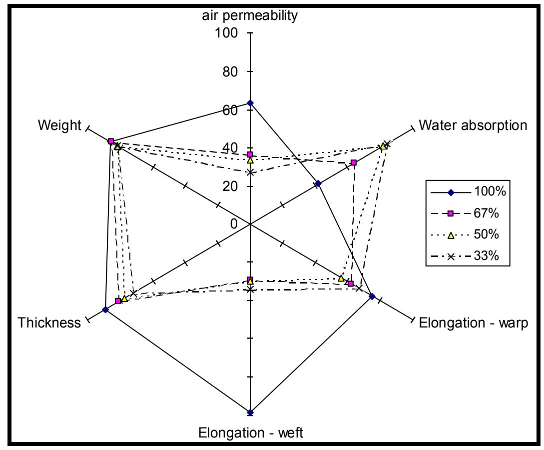

Fig. (16):Radar chart for samples which produced from twill weave structure 3/1 and 22 picks/cm

Conclusion:

- The study proved that, there is an increasing relation between hollow fibers ratio in produced samples and fabric's air permeability (all other executional specifications are constant).
- There is an inverse relation between hollow fibers ratio in produced samples and fabric's water absorption percentage (all other executional specifications are constant).
- The study showed that, there is an increasing relation between hollow fibers ratio in produced samples and fabric's elongation percentage on either warp or weft direction (all other executional specifications are constant).
- The difference of hollow fibers ratio has an effective influence on fabric's thickness. Fabrics produced from 100% hollow fibers verified the least readings where as fabrics produced from 33% hollow fibers and 67% cotton fibers recorded the highest readings (all other executional specifications are constant).
- The study assured that, there is an inverse relation between hollow fibers ratio in produced samples and fabric's weight per square meter (all other executional specifications are constant).
- The study proved that, a sample which produced from 100% polyester hollow fibers, twill weave structure 2/2 and 16 picks/cm is the best sample according to the quality of functional properties (all other executional specifications are constant).

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2/25/2012