

Effect of Some Construction Factors on the Efficiency of Compression Sportswear Fabrics

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Abstract: In recent years, development in next to skin compression active sportswear fabrics has been progressing to perform high functions and achieve comfort. The main purpose of this study was to produce adequate fabric to be used in compression sport fabrics. Woven technique was applied to produce fabrics under study using different constructions (regular hopsack 2/2, twill 1/3, satin 4 and double weave) with warp sets of 80,100 and 120 ends/cm and weft sets of 75,100 and 125 picks/cm. Two textile materials were also employed; Lycra covered with polyester of 50 and 70 denier for warp yarns and textured polyester of 60 detex for weft yarns. Different parameters were studied including fabric structure, warp and weft set and yarn count and their influence on the performance of the end-use fabrics were also studied. On the other hand physical properties including; air permeability, water permeability tensile strength and elongation, abrasion resistance, thickness and weight, were evaluated according to the final product needs. The results demonstrated that some properties such as air and water vapor permeability, abrasion resistance, thickness and weight are influenced by both material type and structure parameters.

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1. Introduction

With economic growing and health conscious being popular among the people, more and more persons are attracted to attending outdoor sports, (1) so the demand for sport apparel is increasing, especially for the comfortable, health and functional sportswear.(2)

Therefore, textiles and clothing industry is undergoing dynamic transformation to meet rapidly changing demands from increasingly value-conscious consumers around the world,(3) specially when it comes to active wear for athletes and exercisers to ensure that people can enjoy sports and other recreational activities without having to worry about getting wet or chilled.(4)

Textile materials are used in virtually every sport from exercising to camping to football, and high performance textile fibers and fabrics are used in uniforms, equipment and sport facilities.(4)

Sports fabrics are generally ultra-breathable and have high heat and moisture management properties, light weight, fast drying properties and feature elasticity properties.(5)

1.1 Next to skin compression sportswear

Compression garments are constructed to have a negative fit where the size of the garment is smaller than that of the body over which they are fitted.(6) These types of garments are widely used in swimwear, skiwear and gymnastics uniforms.(4)

Due to this negative fit, these types of garments generate pressure on the underlying tissue of the human body where the inner surface of these garments is in

full contact with the wearer's skin. Therefore sensorial or tactile comfort is an important part of an overall physiological comfort of this type of sport apparel.(6)

1.2 Comfort properties of compressed garments

For the garment that is worn next to skin, it should have good sweat absorption and sweat releasing property to the atmosphere and fast drying property for getting more tactile comfort.(7) From this point of view, moisture and heat management as well as friction between and skin are two important components in evaluation of the sensorial comfort of fabrics and materials used in compressed sport garments.(6)

Moisture management is defined as the ability of a garment to transport moisture away from the skin to the outer surface,(8) therefore the most important feature of compressed sport garments is to create a stable microclimate next to skin in order to support body's thermoregulatory system, even if the external environment and physical activity change completely, which gives the body a comfortable feeling. (9,10)

Friction between fabric and human body has also a dominant effect on comfort properties Besides that, as it was found that frictional force required for fabric to move against sweating skin resulting from physical activities is much higher than that for movement against dry skin, which means that wet fabric will give an additional stress to the wearer.(11)

1.3 Structure of compression sport garments

Compression sport garments that are used next to skin are usually made of plain or satin woven fabrics. Warp knit made from continuous filament fibers and

weft knits made of spun yarns are also widely used in shirts for active sports.(4)

These porous materials such as woven fabrics, which is used in this research, enable the transmission of energy in the form of heat as well as of substances, such as liquids (perspiration) and gases (air) and therefore are suitable for this kind of sportswear.(9)

1.4 Compression sport garments material

For sportswear, nylon, cotton, polyester/cotton are commonly used, but synthetic fibers are preferred because they don't retain moisture and therefore don't get heavy upon sweating.(4)

In compression sport garments fibers should not absorb moisture, so that moisture or perspiration is wicked away from skin to outer layers of clothing, using the basic idea of capillary action, from whence it can evaporate into atmosphere.(11) Therefore, polyester was the most widely and popularly used fiber because of its favorable characteristics, namely high

strength, dimensional stability, easy care, wrinkle free characteristics besides its low moisture absorption and low cost.(9)

For compression sport garments, spandex, which is a superfine polyurethane fiber that can stretch up to five times its original length and recover immediately, is widely used because it offers close-fitting, stretching and non-restrictive properties.(4)

2. The experimental Work

2.1 Material and methods

This research aimed to produce fabrics suitable for compression sport garments. Woven technique was applied to produce fabrics under study using different constructions (regular hopsack 2/2, twill 1/3, satin 4 and double weave) and two textile materials were also employed, Lycra covered with polyester for warp yarns and textured polyester for weft yarns and table (1) shows specifications of samples under study.

Table (1) specifications of samples under study

No.	Property	Specification
1	Warp type	Textured polyester
2	Weft type	Lycra covered with polyester
3	Count of weft yarns	60 detex
4	Count of warp yarns	50, 70 denier
5	Warp set(ends /cm)	80,100, and 120
6	Weft set (picks / cm)	75,100 and 125
7	Fabric structures	Regular hopsack 2/2, twill 1/3 and satin 4
8	Reed used (dents / cm)	10 dents /cm
9	Denting	8,10 and 12 ends

2.2 Tests applied to samples under study

Several tests were carried out in order to evaluate the performance of the produced fabrics and these tests were:

1-Air permeability of fabrics, this test was carried out according to the British standard (BS 2925) (12)

2- Fabric water permeability were determined according to the (ASTM.-D 449) (13)

3-Tensile strength & elongation at break, this test was carried out according to the (ASTM-D 1682) (14)

4- Abrasion resistance, this test was carried out according to the (ASTM-D1175) (15)

5-Fabric thickness, this test was carried out according to the (ASTM-D1777) (16)

6-Fabric weight, this test was carried out according to the ASTM-D 3776- 79 (17)

3 .Results & discussion

Results of experimental examination on samples under study are presented in the following tables and graphs. Results were statistically analyzed for data listed.

Air permeability test

Table (2) results of air permeability test applied to samples under study

The test	Air permeability ($L^3 / \text{min} \cdot m^2$)																	
	50 denier									70 denier								
Fabric structure	Regular hopsack 2/2			Twill 1/3			Satin 4			Regular hopsack 2/2			Twill 1/3			Satin 4		
Weft set Warp set	80	100	120	80	100	120	80	100	120	80	100	120	80	100	120	80	100	120
100	24	16	11	23	14	9	16	12	6	22	13	8	20	13	10	9	7	5
120	21	14	9	20	12	8	7	7	4	17	11	5	17	9	8	6	6	4
140	18	11	6	15	10	6	6	5	3	15	7	4	14	7	5	4	3	3

It is clear from table (2) and figure (3) that regular hopsack 2/2 has obtained the highest rates of air permeability, whereas satin 4 has obtained the lowest rates but the differences were insignificant.

It is also obvious from the statistical analysis figures (1) and (2) of the air permeability results that there is an inverse relationship between number of ends and picks per cm and air permeability. The researchers can report that the increasing in number of ends and picks decreases spaces between yarns causing an obstruction in air passage leading to the decrease in air permeability.

It was also found from figure (2) that the more yarn count, in the direct system, the less air permeability the fabrics become when all other variables are equal as samples of 70 denier have scored the lowest rates of air permeability compared to samples of 50 denier . This is because that, the increase in yarn counts means increasing in yarns diameters leading to decrease the contact areas between yarns and spaces between yarns will decrease leading to decrease in fabrics air permeability.

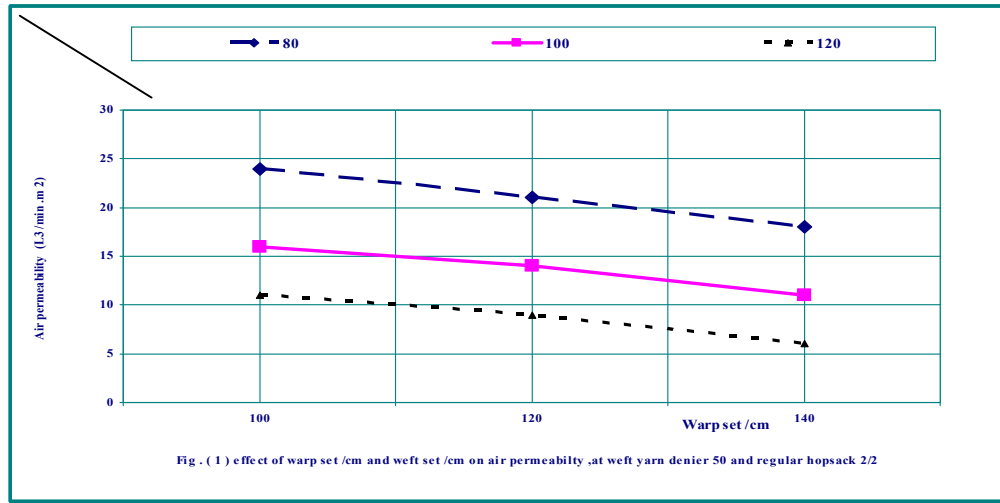


Fig . (1) effect of warp set /cm and weft set /cm on air permeability ,at weft yarn denier 50 and regular hopsack 2/2

Table (3) regression equation and correlation coefficient for the effect of warp and weft set on air permeability, at weft 50 denier and regular hopsack 2/2.

Weft set	Regression equation	Correlation coefficient
80	$Y = -0.15 X + 39$	-0.1
100	$Y = -0.125 X + 28.66667$	-0.993399
120	$Y = -0.125 X + 32.66667$	-0.993399

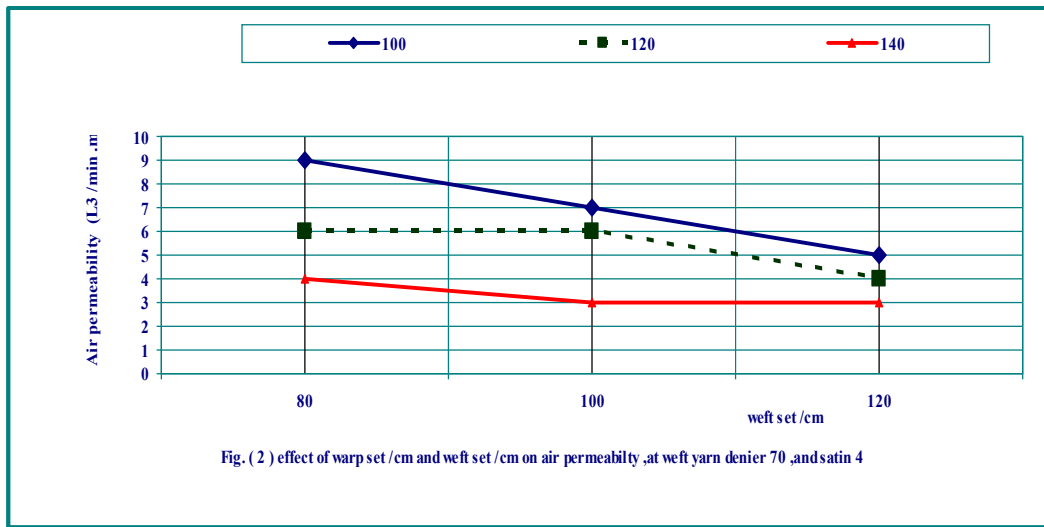


Fig. (2) effect of warp set /cm and weft set /cm on air permeability ,at weft yarn denier 70 ,and satin 4

Table (4) regression equation and correlation coefficient for the effect of warp and weft set on air permeability, at weft 70 denier and satin 4.

Weft set	Regression equation	Correlation coefficient
80	$Y = -0.125 X + 21.33333$	-0.993399
100	$Y = -0.1 X + 17.33333$	-0.960769
120	$Y = -0.5 X + 10$	-1

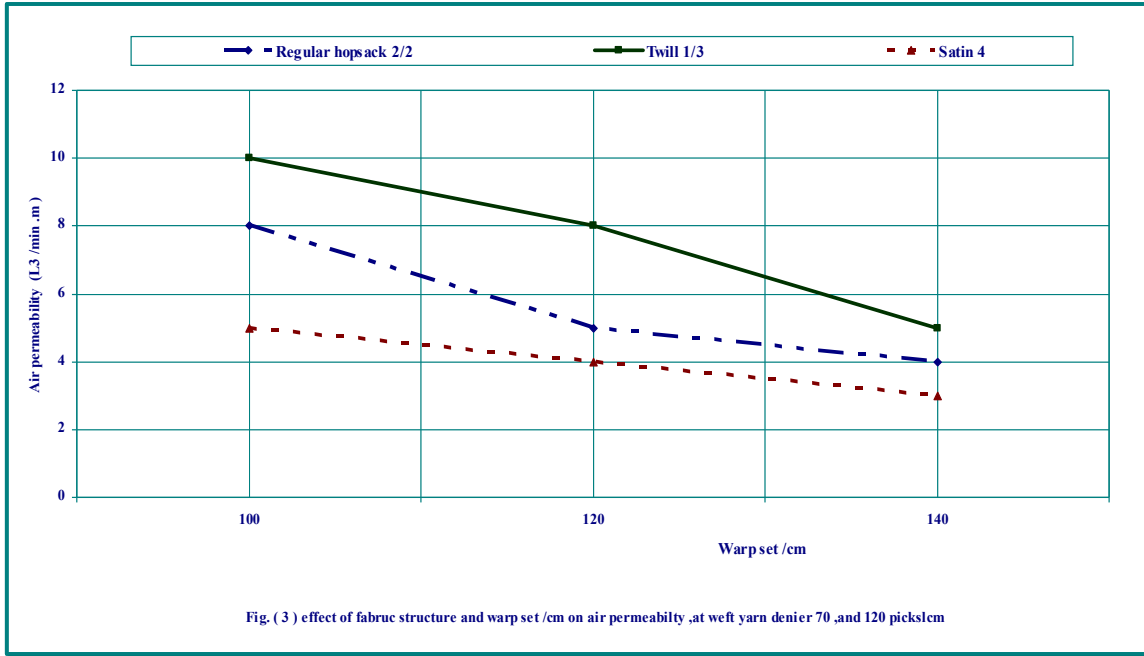


Fig. (3) effect of fabric structure and warp set/cm on air permeability ,at weft yarn denier 70 ,and 120 picks/cm

Table (5) regression equation and correlation coefficient for the effect of warp set and fabric structure on air permeability, at weft 70 denier and 120 picks /cm.

Fabric structure	Regression equation	Correlation coefficient
Regular hopsack 2/2	$Y = -0.1 X + 17.66667$	-0.960769
Twill 2/2	$Y = -0.125 X + 22.66667$	-0.993399
Satin 4	$Y = -0.05 X + 10$	-1

Water permeability

Table (6) results of water permeability test applied to samples under study

The test	Water permeability (sec)																	
	50 denier									70 denier								
Fabric structure	Regular hopsack 2/2			Twill 1/3			Satin 4			Regular hopsack 2/2			Twill 1/3			Satin 4		
Weft set	80	100	120	80	100	120	80	100	120	80	100	120	80	100	120	80	100	120
Warp set 100	35	39	50	39	44	51	53	59	67	44	45	52	48	45	62	48	64	89
120	41	51	54	49	53	54	59	65	82	45	48	56	50	62	77	53	69	96
140	45	53	56	54	57	64	69	84	89	49	58	73	54	59	84	58	92	106

It can be seen from table (6) that the regular hopsack 2/2 have obtained the highest rates of water permeability, followed by twill 1/3 and then satin weave .This is for sack of that, the increase of the number of intersections per unit area for the hopsack 2/2 structure compared to other structures which cause

increasing of the water spaces in the fabric which enhance the capillary action .

It can also be noticed from table (6) and figure (4) that the more densities the warp and weft sets get, the lower water permeability the samples become. This is mainly due to that the increase in number of yarns

increases the contact areas between yarns and decrease void spaces, which decrease or prevent the passage of water.

It was also found from figure (4) that there is an inverse relationship between yarn count, in the direct system, and water permeability the when all other

variables are equal. This is because that, the increase in yarn counts means increasing in yarns diameters leading to decrease the contact areas between yarns and spaces between yarns will decrease leading to decrease in fabrics water permeability.

Table (7) regression equation and correlation coefficient for the effect of warp and weft set on water permeability, at weft 50 denier and regular twill 1/3

Weft set	Regression equation	Correlation coefficient
80	$Y = 0.375 X + 2.3333$	0.981981
100	$Y = 0.325 X + 12.3332$	0.976221
120	$Y = 0.325 X + 17.3332$	0.954919

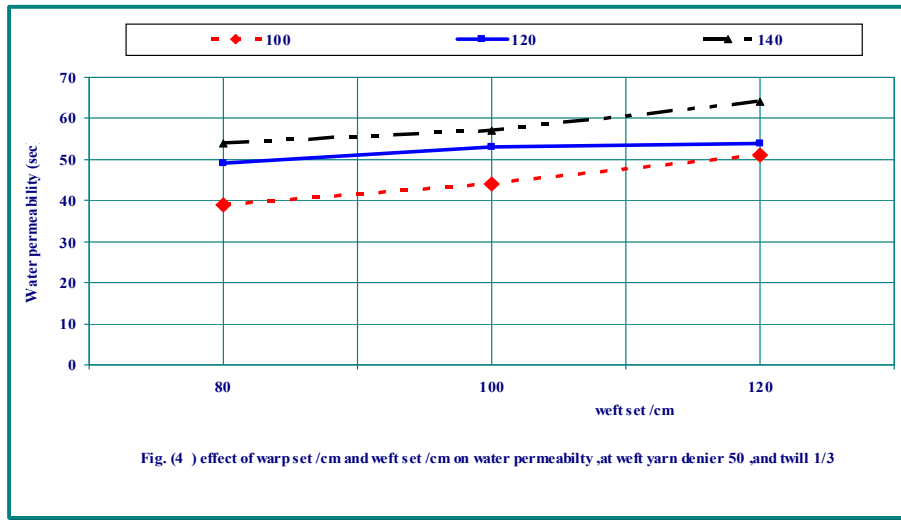
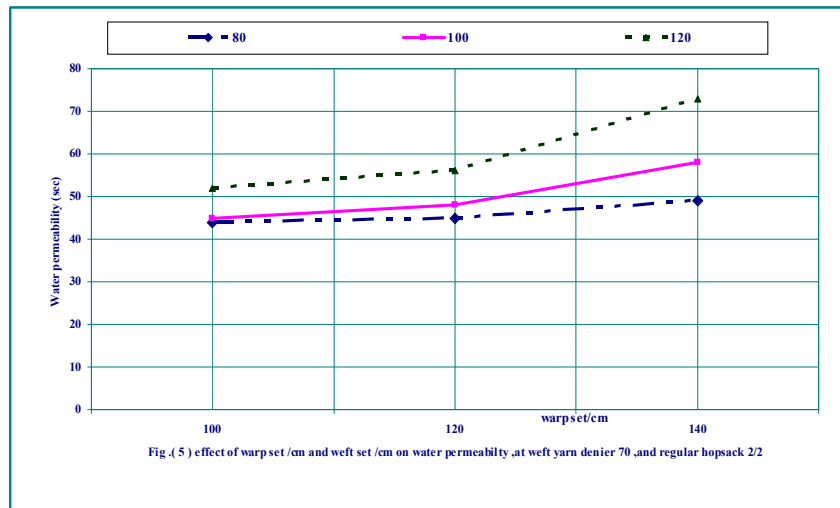


Table (8) regression equation and correlation coefficient for the effect of warp and weft set on water permeability, at weft 70 denier and regular hopsack 2/2

Weft set	Regression equation	Correlation coefficient
80	$Y = 0.125 X + 31$	0.944911
100	$Y = 0.325 X + 11.3333$	0.954919
120	$Y = 0.525 X + 2.6667$	0.941663



Tensile strength

Table (9) results of the tensile strength test applied to samples under study

The test	Tensile strength (kg)																	
	50 denier									70 denier								
Fabric structure	Regular hopsack 2/2			Twill 1/3			Satin 4			Regular hopsack 2/2			Twill 1/3			Satin 4		
Weft set Warp set	80	100	120	80	100	120	80	100	120	80	100	120	80	100	120	80	100	120
100	187	198	235	151	178	221	127	147	208	309	324	348	278	289	306	257	287	298
120	204	249	273	179	206	247	129	185	227	329	351	369	299	307	318	298	308	306
140	227	293	305	208	238	268	168	209	248	348	369	386	318	329	339	325	326	335

It is clear from the diagrams (6), (7) and table (9) that regular hopsack2/2 has scored the highest rates of tensile strength, whereas satin 4 has scored the lowest rates, and this is for the sake of that regular hopsack2/2 structure has the advantage of having short floats and more intersections compared to other structures, leading to regular hopsack weave fabrics to be more compacted and decreases yarns slippage ability and so increase its tensile strength.

It is also obvious from table (9) that samples with denier 70 have recorded the highest tensile strength followed by samples with 50 denier This is due to that yarns of 70 denier are thicker than yarns of 50 and so the spaces between yarns will be decreased leading to the increase in friction areas and decrease slippage

between them causing the produced samples to be higher in their tensile strength.

It is also obvious from figures (6) and (7) that there is a direct relationship between the increase in number of picks and ends per unit area and fabrics tensile strength as samples with 140 end and 120 pick per cm have recorded the highest rates of tensile strength, whereas samples with 100 end and 80 pick per cm have recorded the lowest rates of tensile strength. This is mainly due to that the increase in number of yarns increases the contact areas between yarns and so their resistance to slippage will also increase leading to the increase in fabric tensile strength.

Table (10) regression equation and correlation coefficient for the effect of warp set and fabric structure on tensile strength, at weft 50 denier and 80 picks/cm

Fabric structure	Regression equation	Correlation coefficient
Regular hopsack 2/2	$Y = 0.025 X + 18.3333$	0.886845
Twill 2/2	$Y = 1.425X + 8.3333$	0.99949
Satin 4	$Y = 1 X + 86$	0.996271

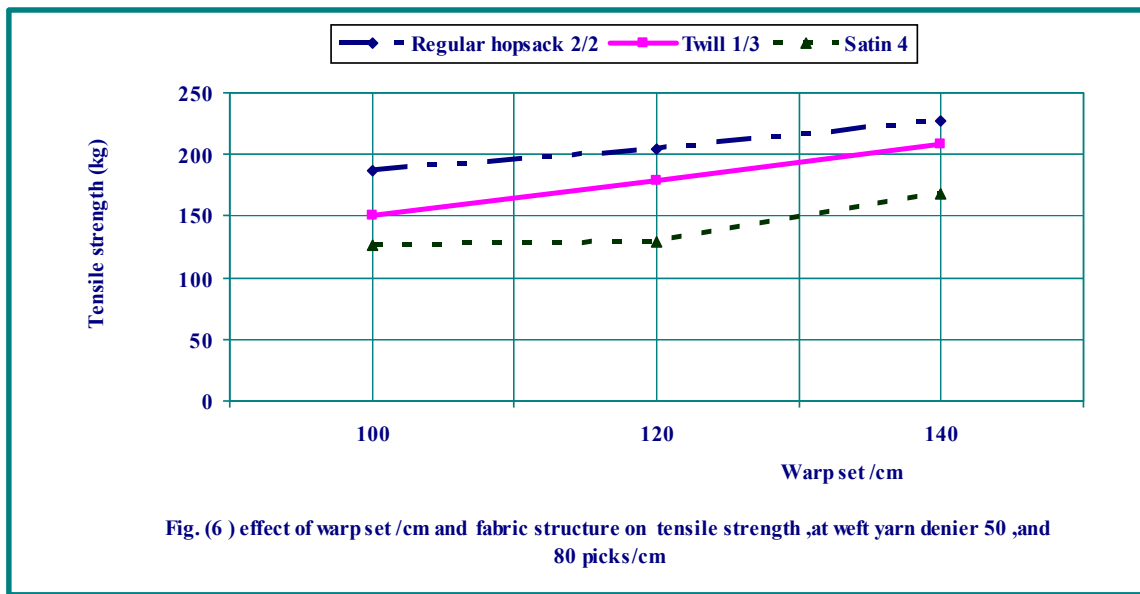


Fig. (6) effect of warp set /cm and fabric structure on tensile strength ,at weft yarn denier 50 ,and 80 picks/cm

Table (11) regression equation and correlation coefficient for the effect of warp set and fabric structure on tensile strength, at weft 70 denier and 120 picks/cm

Fabric structure	Regression equation	Correlation coefficient
Regular hopsack 2/2	$Y = 0.95 X + 253.6667$	0.998158
Twill 2/2	$Y = 0.825X + 222$	0.987829
Satin 4	$Y = 0.925 X + 202$	0.950281

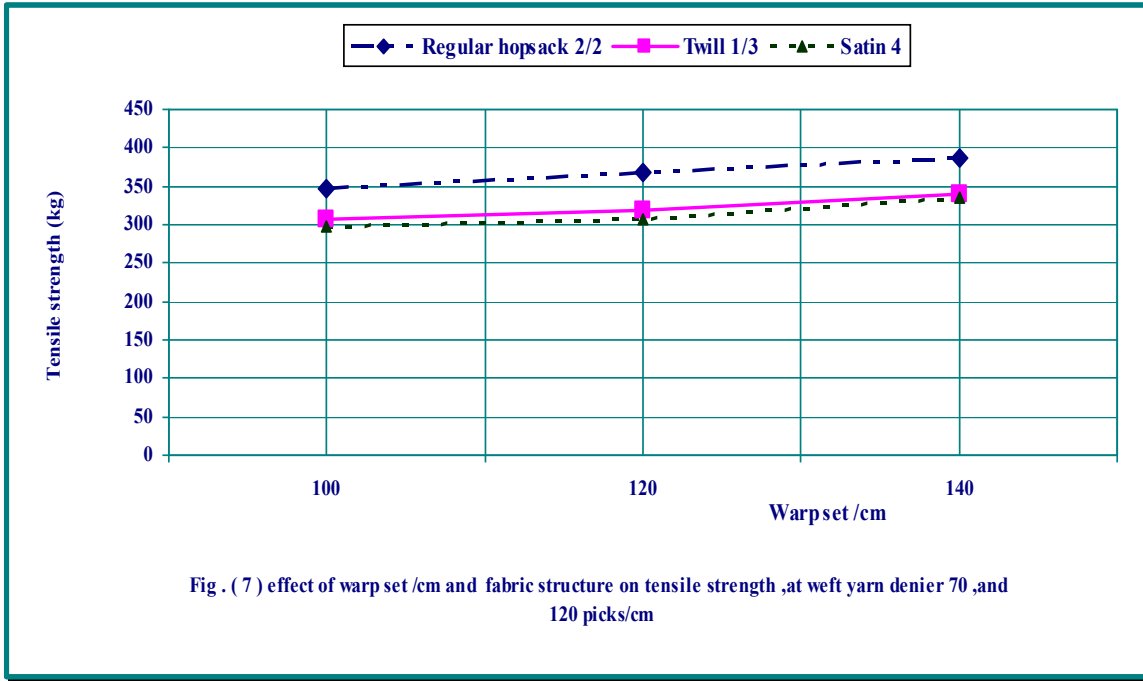


Fig . (7) effect of warp set /cm and fabric structure on tensile strength ,at weft yarn denier 70 ,and 120 picks/cm

Elongation at break test

Table (12) results of the elongation test applied to samples under study

The test	Elongation (%)																	
	50 denier									70 denier								
Fabric structure	Regular hopsack 2/2			Twill 1/3			Satin 4			Regular hopsack 2/2			Twill 1/3			Satin 4		
Weft set Warp set	80	100	120	80	100	120	80	100	120	80	100	120	80	100	120	80	100	120
100	47	44	44	47	49	47	51	51	46	41	40	35	45	41	40	47	43	44
120	45	43	41	45	45	43	48	47	42	39	38	32	44	40	38	45	42	42
140	42	41	39	43	44	41	46	43	40	38	36	30	42	38	35	44	38	35

It is obvious from diagram (8) that satin weave has recorded the highest rates of elongation, whereas regular hopsack 2/2 has recorded the lowest rates. We can report that because regular hopsack 2/2 is stronger due to its intersections, so its resistance to slippage under load will also increase leading to the decrease in fabric elongation.

We can also notice from figure (9), that samples made of 70 denier have obtained the lowest rates of elongation, whereas samples made of 50 denier have recorded the highest rates. This is due to that fabrics of finer yarns have less contact areas compared to fabrics

of thicker yarns for the same unit area, and so friction between yarns will be decreased and hence their resistance to slippage will be decreased leading to a decrease in fabric elongation.

It is also clear from table (12) and figures (8) and (9) that, there is an inverse relationship between number of ends and picks per cm and elongation. This is mainly due to that the increase in yarn set per unit area means that contact areas between yarns will increase and its resistance to slippage under load will also increase leading to the decrease in fabric elongation.

Table (13) regression equation and correlation coefficient for the effect of warp and fabric structure on elongation, at weft 50 denier and 100 picks/cm

Fabric structure	Regression equation	Correlation coefficient
Regular hopsack 2/2	$Y = -0.1 X + 50$	0.941663-
Twill 2/2	$Y = -0.075 X + 48.6667$	-0.981981
Satin 4	$Y = -0.125 X + 56$	0.944911-

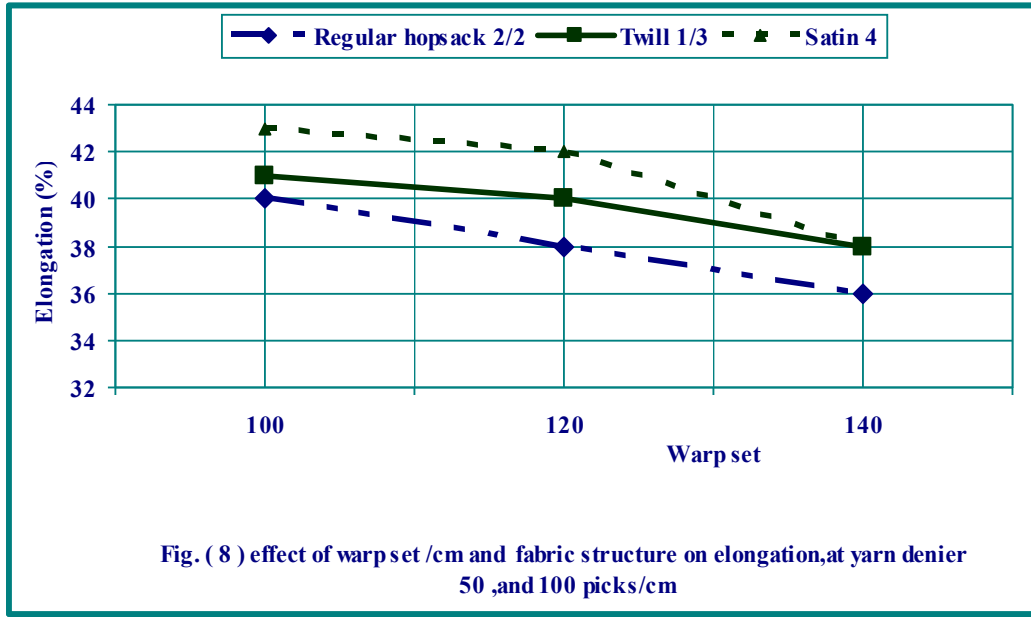
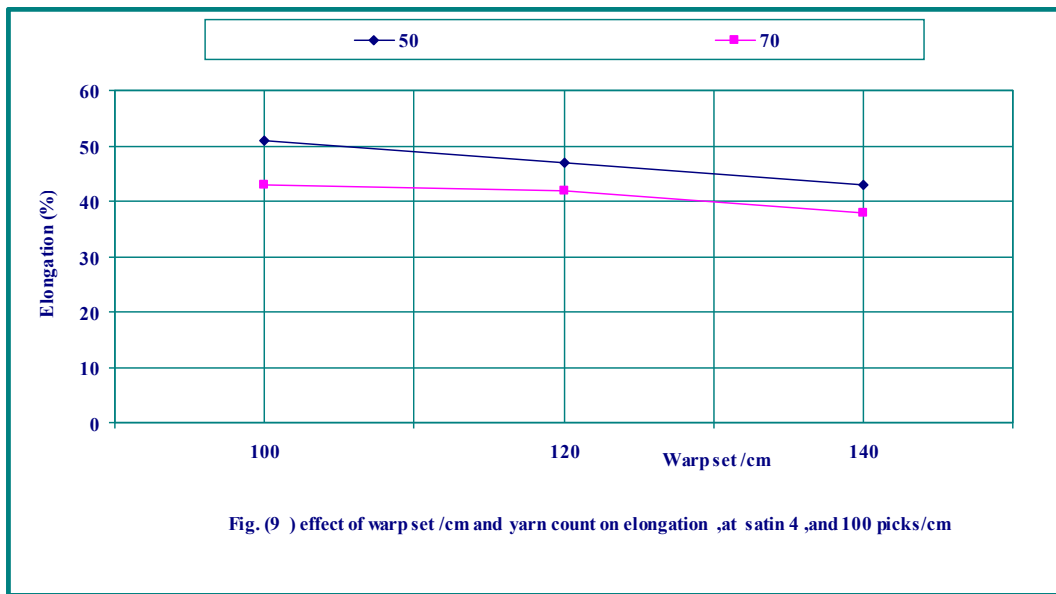


Table (14) regression equation and correlation coefficient for the effect of warp set and yarn count on elongation, at satin 4 and 100 picks/cm

Yarn count	Regression equation	Correlation coefficient
50	$Y = -0.2 X + 71$	0.1-
70	$Y = -0.125 X + 56$	-0.944911



Abrasion resistance test

Table (15) results of the abrasion resistance test applied to samples under study according to the loss in thickness (%)

The test	Abrasion resistance [loss in thickness (%)]																	
	50 denier									70 denier								
Fabric structure	Regular hopsack 2/2			Twill 1/3			Satin 4			Regular hopsack 2/2			Twill 1/3			Satin 4		
	Weft set	80	100	120	80	100	120	80	100	120	80	100	120	80	100	120	80	100
100	0.35	0.31	0.19	0.36	0.34	0.24	0.47	0.44	0.37	0.34	0.27	0.21	0.26	0.21	0.18	0.22	0.20	0.11
120	0.30	0.27	0.15	0.32	0.31	0.21	0.42	0.40	0.30	0.29	0.21	0.17	0.20	0.18	0.16	0.19	0.18	0.10
140	0.25	0.21	0.12	0.28	0.26	0.16	0.39	0.35	0.29	0.24	0.19	0.10	0.17	0.15	0.10	0.17	0.15	0.09

Table (16) results of abrasion resistance test applied to samples under study according to loss in weight (%)

The test	Abrasion resistance [loss in weight (%)]																	
	50 denier									70 denier								
Fabric structure	Regular hopsack 2/2			Twill 1/3			Satin 4			Regular hopsack 2/2			Twill 1/3			Satin 4		
	Weft set	80	100	120	80	100	120	80	100	120	80	100	120	80	100	120	80	100
100	2.00	1.84	1.56	2.83	2.37	2.07	3.10	2.78	2.35	1.70	1.64	1.35	1.60	1.46	1.25	1.50	1.40	1.18
120	1.94	1.53	1.50	2.60	2.18	1.91	2.82	2.61	2.18	1.61	1.49	1.20	1.51	1.41	1.01	1.42	1.32	0.87
140	1.71	1.38	0.95	2.53	1.95	1.71	2.30	2.04	1.85	1.50	1.41	1.00	1.42	1.36	0.76	1.31	1.22	0.60

It is obvious from the results in table (15) and (16) that regular hopsack 2/2 has recorded the highest rates of abrasion resistance (lost weight and thickness ratio), followed by twill 2/2 whereas satin 4 has recorded the lowest rates, but the differences were insignificant.

It is also clear from the diagrams (10) and (11), that there is a direct relationship between number of picks and ends per unit area and abrasion resistance. This is for the sake of that the increase in number of yarns per unit area cause fabrics to be more compacted

due to the decrease in spaces between yarns leading to the increase in fabric abrasion resistance.

From figure (10) and table (15) and (16), we can also notice that samples made of 50 denier have obtained the lowest rates of abrasion resistance, whereas samples made of 70 denier have obtained the highest rates. This is probably due to that the more diameter the yarns get the more increased cover factor the fabric become which leads to a more compacted fabric and so its resistance to abrasion will be increased.

Table (17) regression equation and correlation coefficient for the effect of warp set and yarn count on abrasion resistance, at twill 1/3 and 100 picks/cm

Yarn count	Regression equation	Correlation coefficient
50	$Y = -0.002 X + 0.59333$	0.989743-
70	$Y = -0.0015 X + 0.36$	0.1-

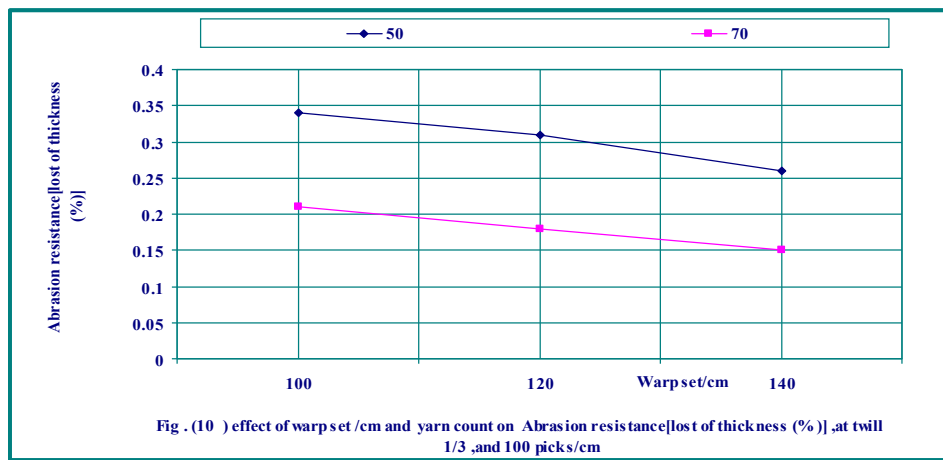
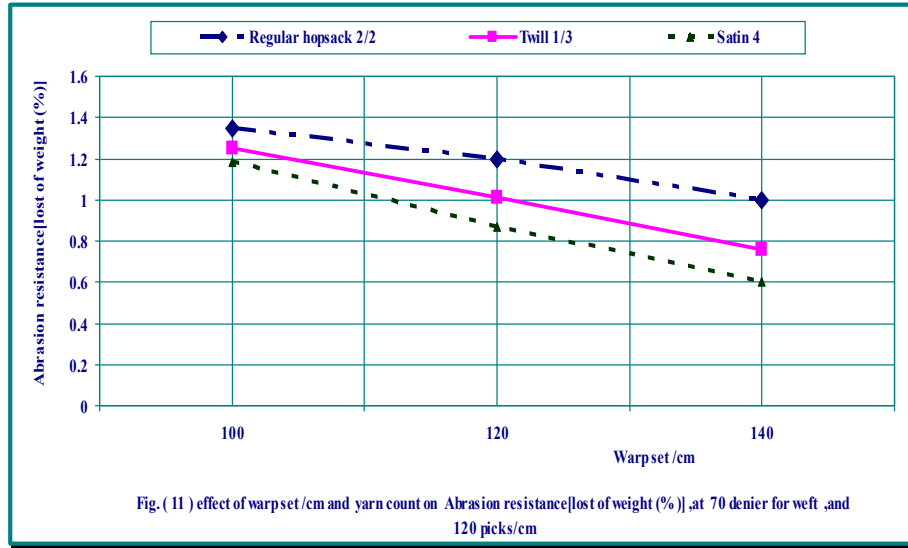


Fig . (10) effect of warp set /cm and yarn count on Abrasion resistance[lost of thickness (%)], at twill 1/3 ,and 100 picks/cm

Table (18) regression equation and correlation coefficient for the effect of warp and fabric structure on abrasion resistance, at weft 70 denier and 120 picks/cm

Fabric structure	Regression equation	Correlation coefficient
Regular hopsack 2/2	$Y = -0.145 X + 2.62333$	0.999208-
Twill 2/2	$Y = -0.01225 X + 2.476667$	-0.999931
Satin 4	$Y = -0.145 X + 2.62333$	0.996616-



Thickness test

Table (19) results of thickness test applied to samples under study

The test	Thickness (mm)																	
	50 denier									70 denier								
Fabric structure	Regular hopsack 2/2			Twill 1/3			Satin 4			Regular hopsack 2/2			Twill 1/3			Satin 4		
Weft set Warp set	80	100	120	80	100	120	80	100	120	80	100	120	80	100	120	80	100	120
100	0.44	0.44	0.50	0.43	0.43	0.45	0.41	0.42	0.45	0.43	0.46	0.51	0.41	0.44	0.49	0.39	0.46	0.48
120	0.45	0.47	0.47	0.42	0.44	0.46	0.43	0.43	0.46	0.45	0.49	0.52	0.43	0.47	0.50	0.40	0.47	0.50
140	0.44	0.48	0.51	0.45	0.46	0.48	0.42	0.45	0.47	0.48	0.50	0.55	0.47	0.51	0.52	0.45	0.49	0.51

It is clear from diagram (12), that regular hopsack 2/2 has recorded the highest rates of thickness, followed by twill 2/2 and then satin 4, which achieved the lowest rates, but the differences between them was insignificant. This is mainly for sake of that floats direction of hopsack 2/2 structure give it the advantage of having ridges on fabric surface giving it the ability of being thicker than other structures.

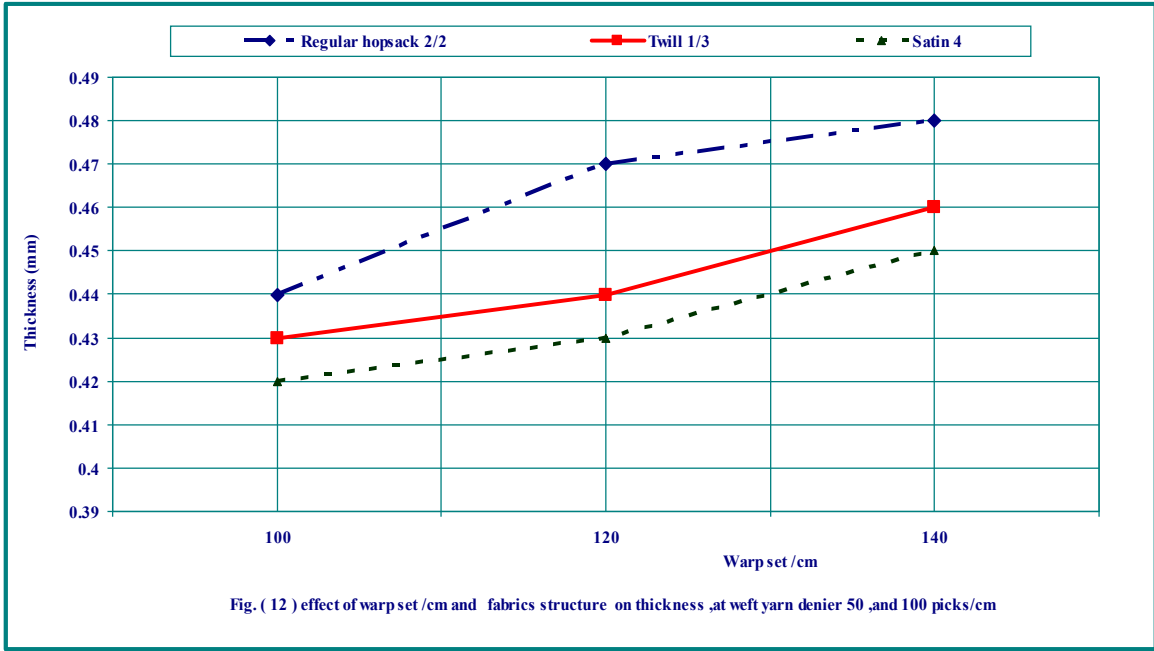
Another reason for differences in thickness is yarn count, as samples with denier 70 have recorded the

highest thickness followed by samples with 50 denier; this is due to that yarns of 70 denier are thicker than yarns of 50, causing the produced samples to be thicker.

It was also found that the more yarns per unit area the more thicker the samples become, so samples with 140 end and 120 pick per unit area have recorded the highest rates of thickness, whereas samples with 100 end and 80 pick per unit area have recorded the lowest rates.

Table (20) regression equation and correlation coefficient for the effect of warp set and fabric structure on thickness, at weft 50 denier and 100 picks/cm

Fabric structure	Regression equation	Correlation coefficient
Regular hopsack 2/2	$Y = 0.001 X + 0.343333$	0.96076
Twill 2/2	$Y = 0.00075X + 0.353333$	0.981981
Satin 4	$Y = 0.00075 X + 0.343333$	0.981981



Weight test

Table (21) results of weight test applied to samples under study

The test	Weight (g/m ²)																	
	50 denier									70 denier								
Fabric structure	Regular hopsack 2/2			Twill 1/3			Satin 4			Regular hopsack 2/2			Twill 1/3			Satin 4		
Weft set Warp set	80	100	120	80	100	120	80	100	120	80	100	120	80	100	120	80	100	120
100	141	164	190	142	163	192	142	162	194	215	253	271	206	258	266	207	257	271
120	164	185	211	162	190	211	161	191	257	241	287	302	241	284	302	242	264	288
140	185	200	224	185	199	225	184	201	225	265	310	325	267	312	327	264	312	312

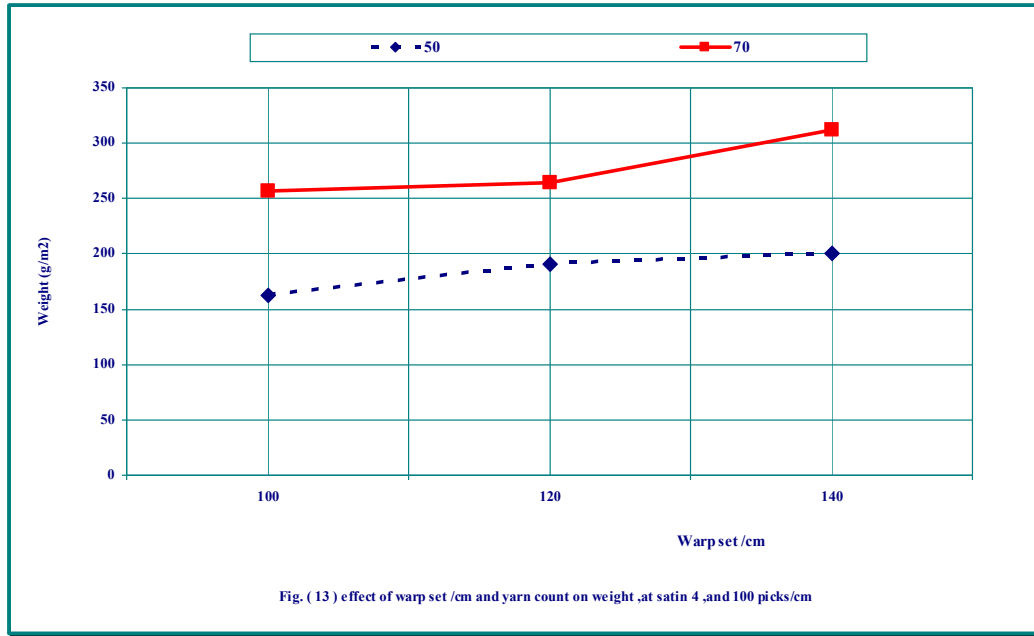
It is clear from the tables that regular hopsack2/2 has scored the lowest rates of weight, whereas satin 4 has scored the highest rates. We can state that this is due to the difference in number of intersections per unit area for each weave structure, so crimp percentage of regular hopsack structure is the highest because of the increase in the bending curve of yarns round each other leading to the increase in fabric weight but the differences between the three structures were insignificant.

It was also found that the more yarns per unit area the more weight the samples become, so samples with 140 ends and 120 picks per cm have recorded the highest weight, whereas samples with 100 ends and 80 picks per cm have recorded the lowest weight.

It is also obvious from the statistical analysis and figure (13) that samples with denier 100 have recorded the highest weight followed by samples with 70 denier This is because that, the increase in yarn counts means increasing in yarns diameters leading to the increase in fabric weight.

Table (22) regression equation and correlation coefficient for the effect of warp set and yarn count on weight, at satin 4 and 100 picks/cm

Yarn count	Regression equation	Correlation coefficient
50	Y = 0.975 X + 67.66667	0.962645
70	Y = 1.375X + 112.6667	0.91854



References

- Zheng,L,," A Survey of Outdoor Sportswear Requirements for Chinese Consumers", Advanced Materials Research Journal, Vols. 479-481, 2012. p676-679.
- Liu,P., and Liu, Y., "Developments of Hydroscopic and Fast Drying Sportswear Fabrics", Advanced Materials Research Journal, Vol.503-504,2012.p178-181.
- Wu,Y., Chen, R., *et al* "Intelligent Clothing for Automated Recognition of Human Physical Activities in Free-living Environment", The Journal of the Textile Institute,Vol.103, No.8,2012.p806.
- Adanur, S., "Sports and Recreation Textiles", Wellington Sears Handbook of Industrial Textiles, Technomic Publishing Company Inc., Lancaster, Pennsylvania, 1995.p475-490.
- Uttam, D., "Active Sportswear Fabrics", International Journal of IT, Engineering and Applied Science Research, Vol.2, No.1, January, 2013.p34-39.
- Troynikov, O., Ashayeri,E., and Fuss, F.,K., "Tribological Evaluation of Sportswear With Negative Fit Worn Next to Skin", Journal of Engineering Tribology,Nov.,2011.
- Hill, R., "Fibers and Fabrics in Sports", Textiles, Vol.14, No.2,1985.p30-36.
- Nilgun, O., Gamze, S., *et al.*, "A Study on the Moisture Transport Properties of the Cotton Knitted Fabrics in Single Jersey Structure", Journal of Textiles and Apparel, Vol.19, Issue 3, 2009.p218-223.
- Varshney, R., K., Kothari, V., K., and Dhamija, S., "A Study on Thermophysiological Comfort Properties of Fabrics in Relation to Constituent Fiber Fineness and Cross-sectional Shapes", The Journal of the Textile Institute, Vol.101, No.6, June, 2010.p495-505.
- Das, B., Das, A., and Others, "Effect of Fiber Diameter and Cross-sectional Shape on Moisture Transmission Through Fabrics", Fibers and Polymers, Vol.9, No.2, 2008.p225-231.
- Bohringer, A., "The Function Determines the Finish", International Textile Bulletin, Vol.4, 1998. p28-31.
- B.S. 2925: 88 "British Standard Method for Determining the Air permeability.
- ASTM-D 4491-92 "British standard method for determining the water permeability".
- ASTM-D 1682 "Standard test method for measuring tensile strength and elongation at break".
- ASTM-D 1175 -71 "Standard Test Method for Measuring Abrasion Resistance".
- ASTM-D 1777-84 "Standard Test Method for Measuring Thickness of Textile Materials".
- ASTM-D 3776- 79 "Standard Test Method for Weight of Textile Materials".