"Achieving Optimum Scientific Standards for Producing Fabrics Suitable for Car Safety Seat Belts"

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Abstract

This research is an attempt to produce fabrics suitable for being used as car safety seat belts .All samples in this research were produced with textured polyester filament yarns using three woven structures ,three warp sets were also used , with three weft sets using two different yarns counts. Most samples have achieved the expected results .

I. Introduction

Technical textiles is the fast growing segment of the global textile market and its current growth rate is changing from 3 % to 5 % annually [(1)] ,as we find hygiene products ,medical textiles ,geotextiles ,geonets ,flooring carpets ,roofing materials ,leather substances ,automotive textiles ,shoe materials ,decorative felts ,etc, adding value in our live style. [(2)]

According to the Textile Institute in Manchester ,technical textiles are textile materials intended for end uses other than non–protective clothing ,household furnishing and floor covering ,where the fabric or fibrous components is selected principally but not exclusively for its performance properties as opposed to its aesthetic or decorative characteristics. [(3)]

Automotive textiles is considered one of the most important markets in the technical textiles sector [(4)] with the increasing scale of automobile production ,and consequently its worldwide stock ,the proportion of textiles in a motor car is rising in response to more stringent comfort and safety requirements [(5)]

Approximately 50 square yards of textile materials is used in an average car [(6)] ,nearly 75 % of them are used for tire cord fabrics and seat belts , the remainder goes into helmets ,air bags, body covers, roof liners ,interior fabrics and heat and sound insulation felts .[(7)] Seat belts ,used as safety devices ,are one of the newest applications for textiles in automobiles and has spurred a huge market for technical textiles that is still experiencing considerable growth and development .[(8)]

safety seat belts , safety seat belt is an energy absorbing device is designed to keep the load imposed on a victim's body during a crash down to survivable limits .[(9)] Seat belts are an easy to use ,effective and inexpensive means of protection in an accident .

There are various types of seat belts depending on the vehicle. In passenger cars ,the seat belt fits across the lap and diagonally across the chest which is the most widely used type in the world .In passenger airplanes , the simple lap strap is used that does not restrain the upper part of the body .Racing drivers wear a full harness which consists of a strap over each shoulder and a lap belt .[(6)]

Seat belts are woven narrow fabrics in twill or satin construction .Nylon was used in some early seat belts ,[(8)] but because of its superb mechanical performance ,polyester is now exclusively used worldwide. Polyester also provides high dimensional stability ,good abrasion resistance ,excellent resistance to photo-oxidative degradation ,and high light fastness, which are considered the major requirements in a good seat belt .[4]

A properly designed seat belt should provide non-recoverable extension or stretch during the collision to reduce the deceleration forces on the body (elastic stretch is not wonted since it may cause whiplash damage) .[6] An efficient seat belt will only allow its wearer to move forward a maximum of about 30 cm by controlled extension of the belt to avoid contact with any fixed part of the car. [8] Seat belts need to be replaced after a major accident ,otherwise ,a seat belt should last as long as life of the car .[6]

2. The experimental Work

This research concerns with producing fabrics suitable for Car safety seat belts. All samples in the research were produced with textured polyester yarns using three woven structures (regular hopsack 2/2 ,twill 2/2 and satin 4) .Three warp sets were also used (90,110 and 130 end /cm) , with three weft sets (80 ,100 and 120 pick/cm) using two different yarns counts (70 and 100 denier)

Table (1) specifications of all samples, produced in this research

No	Property	Specification
1	Warp type	Polyester
2	Weft type	Polyester
3	Count of warp yarns	70 and 100 denier
5	Count of weft yarns	70 and 100 denier
6	Warp set (ends / cm)	90,110 and 130
7	Weft set (picks / cm)	80,100 and 120
8	Fabric structures	Regular hopsack 2/2, twill 2/2 and satin 4
9	Reed used	10 dents /cm
10	Denting	9,11and 13 end /dent

Tests

Several tests were carried out in order to evaluate the produced fabrics, these tests were:-

1-**The tensile strength & elongation at break**, this test was carried out according to the (ASTM-D 1682) [10]
2- **Abrasion resistance**, this test was carried out according to the (ASTM-D1175) [11]
3-**Fabric thickness,** this test was carried out according to the (ASTM-D1777) [12]
4-**Fabric weight,** this test was carried out according to the ASTM-D 3776- 79 [13]

3.Results and Discussion

Results of experimental tests carried out on the produced samples were statistically analyzed and presented in the following tables and graphs.

Tensile strength

Table (2) results of tensile strength test applied to samples produced with denier 70.

The test	**Tensile strength (kg)**								
Number of picks/cm	**80**			**100**			**120**		
Warp set / Fabric structure	**90**	**110**	**130**	**90**	**110**	**130**	**90**	**110**	**130**
Regular hopsack 2/2	170	190	228	190	241	266	228	286	296
Twill 2/2	146	172	216	168	199	242	201	232	263
Satin 4	120	142	204	122	178	222	162	205	244

Table (3) results of tensile strength test applied to samples produced with denier 100

The test	**Tensile strength (kg)**								
Number of picks/cm	**80**			**100**			**120**		
Warp set / Fabric structure	**90**	**110**	**130**	**90**	**110**	**130**	**90**	**110**	**130**
Regular hopsack 2/2	302	318	342	324	346	365	342	362	381
Twill 2/2	270	285	299	293	304	311	313	32٧	336
Satin 4	252	280	293	292	302	300	318	31٨	32٨

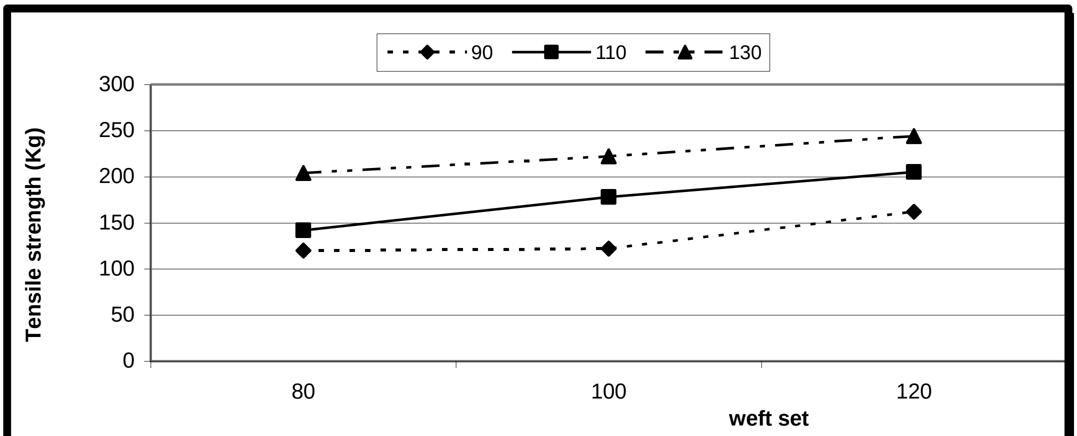

Fig. (1) effect of warp and weft set on tensile strength, at denier 70 and satin 4

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

Warp set	Regression equation	Correlation coefficient
90	Y =1.05X +29.666	0.9٩٨٣٣
110	Y =1.575X +17. 5	0.996615
130	Y =1X +123.333	0.9٩٨٣٣

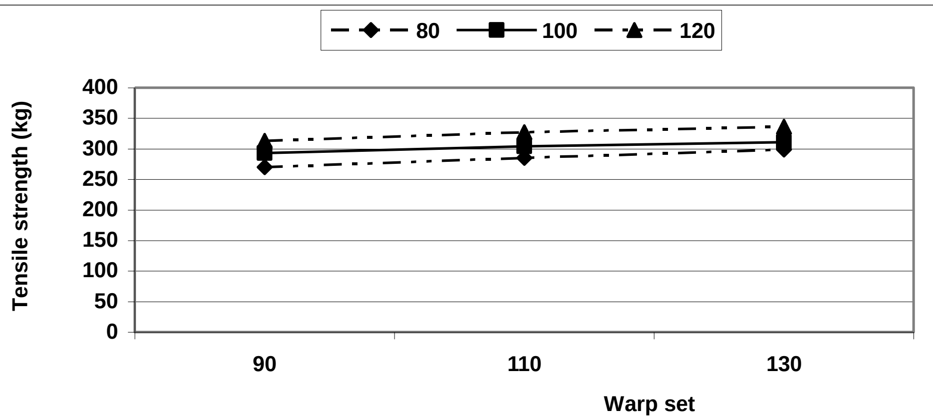

Fig. (2) effect of warp and weft set on tensile strength, at denier 100 and twill 2/2

Table (٥) regression equation and correlation coefficient for the effect of warp and weft set on tensile strength, at denier 100 and twill 2/2.

Fabric structure	Regression equation	Correlation coefficient
Regular hopsack 2/2	Y =٠.9٧٥X +2٥٤.٤١٦٦	0.9٩٩٨٩٠
Twill 2/2	Y =٠.٥٧٥X +2٦٢. ٠٨٣٣	0.9٩٢٢١٥
Satin 4	Y =٠.٢٥X +٢٩٣.٨٣٣٣	0.٨٦٦٠٢٥

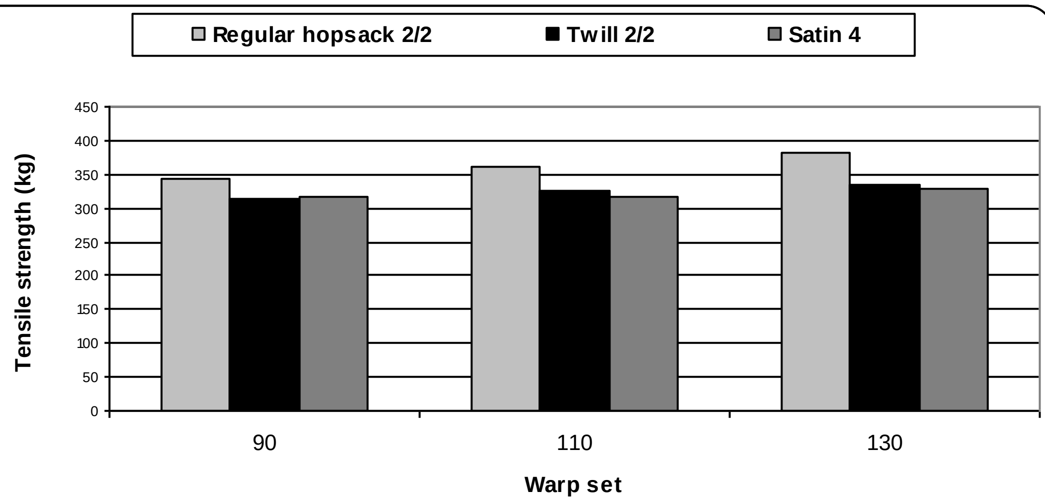

Fig. (3) effect of warp set and fabric structure on tensile strength, at denier 100 and 120 pick/cm

Table (٦) regression equation and correlation coefficient for the effect of warp set and fabric structure on tensile strength, at denier 100 and 120 pick/cm.

Warp set	Regression equation	Correlation coefficient
90	Y =٠.925X +222.833	0.980039
110	Y =1.05X +200. 333	0.988491
130	Y =1.075X +184.5	0.9٩99189

It is clear from the diagrams and tables 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 being stronger than other structures which means it has higher tensile strength.

It is also obvious from the statistical analysis that samples with denier 100 have recorded the highest tensile strength followed by samples with 70 denier This is due to that yarns of 100 denier are thicker than yarns of 70 and so the spaces between yarns will be decreased leading to the increase in friction areas between them causing the produced samples to be higher in their tensile strength .

It was also found that the more yarns per unit area the more tensile strength the samples become, so samples with 130 end per cm and 120 pick per cm have recorded the highest rates of tensile strength, whereas samples with 90 end per cm and 80 pick per cm have recorded the lowest rates of tensile strength..

Elongation

Table (7) results of elongation test applied to samples produced with denier 70.

The test	**Elongation (%)**								
Number of picks/cm	**80**			**100**			**120**		
Warp set / Fabric structure	**90**	**110**	**130**	**90**	**110**	**130**	**90**	**110**	**130**
Regular hopsack 2/2	51	49	48	49	46	45	46	45	42
Twill 2/2	52	51	49	50	47	46	49	46	44
Satin 4	54	53	50	51	50	47	50	47	45

Table (8) results of elongation test applied to samples produced with denier 100

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The test	**Elongation (%)**								
Number of picks/cm	**80**			**100**			**120**		
Weft set / Fabric structure	**90**	**110**	**130**	**90**	**110**	**130**	**90**	**110**	**130**
Regular	44	43	40	43	41	36	41	40	35

hopsack 2/2									
Twill 2/2	50	47	45	49	46	43	47	43	40
Satin 4	52	49	48	50	47	45	47	45	42

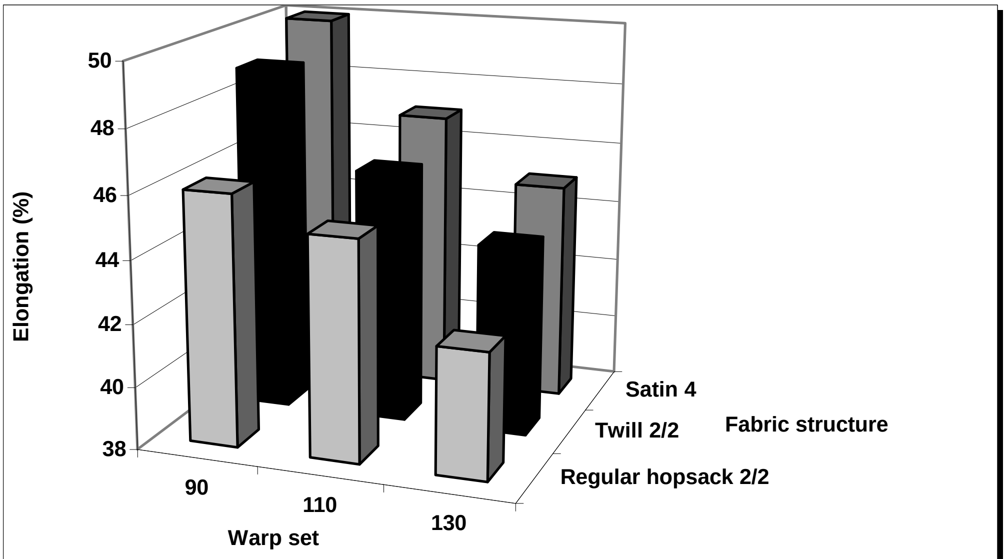

Fig. (4) effect of warp set and fabric structure on elongation, at 120 pick/cm and denier 70

Table (9) regression equation and correlation coefficient for the effect of warp set and fabric structure on elongation, at denier 70 and 120 picks/cm

Fabric structure	**Regression equation**	**Correlation coefficient**
Regular hopsack 2/2	Y =-0.1X +55.3333	-0.960769
Twill 2/2	Y =-0.125X +60.0833	-0.993399
Satin 4	Y =-0.125X +61.0833	-0.993399

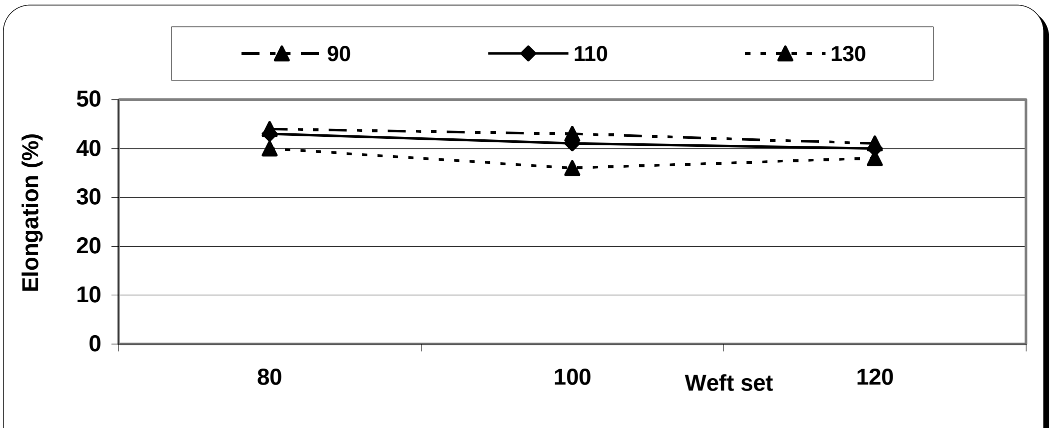

Fig. (5) effect of warp and weft set on elongation, at 120 pick/cm , denier 100 and regular hopsack2/2

Table (10) regression equation and correlation coefficient for the effect of warp and weft set on elongation, at denier ١٠0 and regular hopsack 2/2.

Warp set	Regression equation	Correlation coefficient
90	Y =-0.075X +50.1666	-0.98198
110	Y =-0.075X +48. 833	-0.98198
130	Y =-0.175X +21.5	-0.970725

It is obvious from the diagrams that satin 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 ,so its resistance to slippage under load will also increase leading to the decrease in fabric elongation.

We can also notice that samples made of 100 denier have obtained the lowest rates of elongation, whereas samples made of 70 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 the diagrams 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.

Abrasion resistance

Table (11) results of abrasion test applied to samples produced with denier 70

The test	**Lost of thickness (%)**								
Number of picks/cm	**80**			**100**			**120**		
Warp set / **Fabric structure**	**90**	**110**	**130**	**90**	**110**	**130**	**90**	**110**	**130**
Regular hopsack 2/2	0.39	0.35	0.21	0.35	0.31	0.17	0.30	0.26	0.14
Twill 2/2	0.42	0.37	0.29	0.38	0.34	0.24	0.32	0.29	0.18
Satin 4	0.53	0.47	0.42	0.45	0.43	0.33	0.40	0.38	0.30

Table (12) results of abrasion test applied to samples produced with denier ١٠٠.

The test	**Lost of thickness (%)**								
Number of picks/cm	**80**			**100**			**120**		
Warp set / **Fabric structure**	**90**	**110**	**130**	**90**	**110**	**130**	**90**	**110**	**130**
Regular hopsack 2/2	0.26	0.23	0.13	0.21	0.20	0.12	0.19	0.17	0.10
Twill 2/2	0.31	0.25	0.21	0.25	0.22	0.18	0.22	0.20	0.13
Satin 4	0.38	0.31	0.26	0.32	0.26	0.22	0.27	0.23	0.17

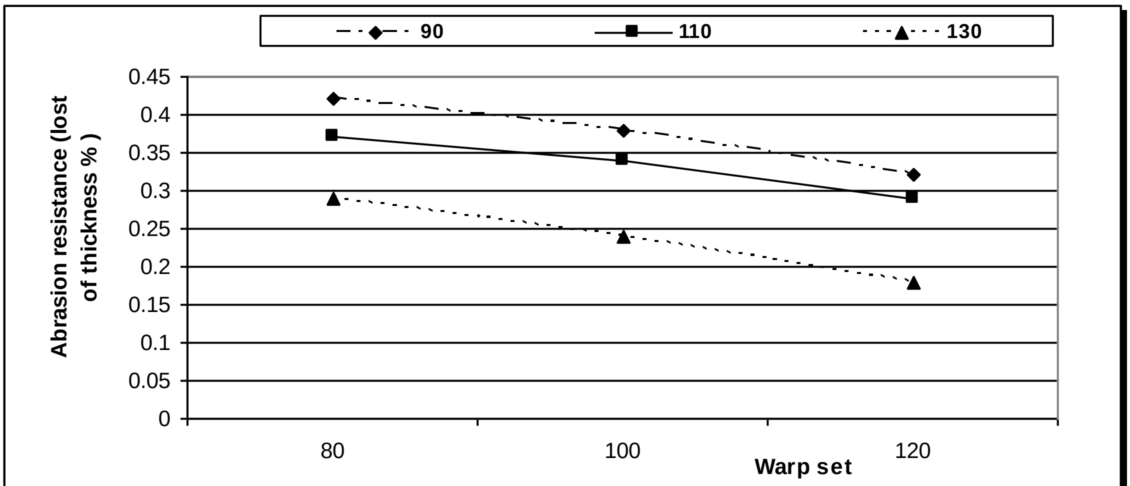

Fig. (6) effect of warp set and fabric structure on abrasion resistance (lost of thickness), at denier 70 and twill 2/2

Table (13) regression equation and correlation coefficient for the effect of warp and weft set on abrasion resistance (lost of thickness), at denier 70 and twill 2/2.

Fabric structure	Regression equation	Correlation coefficient
Regular hopsack 2/2	Y =-0.0045X +0.771667	-0.952217
Twill 2/2	Y =-0.0035X +0.705	-0.970725
Satin 4	Y =-0.003X +0.7333	-0.933257

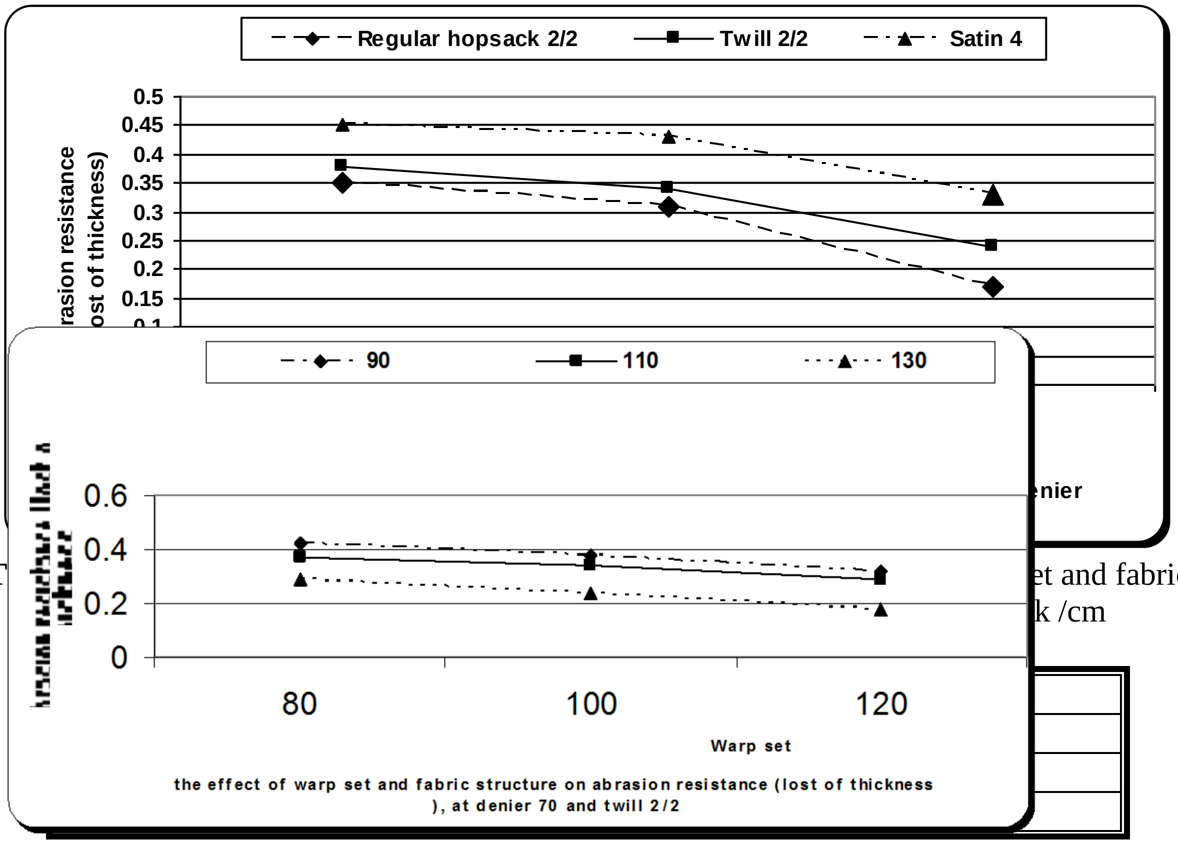

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Table (15) results of abrasion test applied to samples produced with denier 70

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The test	Lost of weight (%)								
Number of picks/cm	80			100			120		
Warp set / Fabric structure	90	110	130	90	110	130	90	110	130
Regular hopsack 2/2	2.04	1.89	1.61	1.96	1.57	1.53	1.75	1.41	0.99
Twill 2/2	2.86	2.42	2.11	2.63	2.21	1.95	2.43	1.99	1.76
Satin 4	3.13	2.81	2.39	2.87	2.65	2.21	2.32	2.1	1.89

Table (16) results of abrasion test applied to samples produced with denier 100.

The test	Lost of weight (%)								
Number of picks/cm	80			100			120		
Warp set / Fabric structure	90	110	130	90	110	130	90	110	130
Regular hopsack 2/2	1.52	1.42	1.19	1.46	1.32	0.89	1.35	1.24	0.61
Twill 2/2	1.62	1.49	1.28	1.53	1.42	1.01	1.43	1.36	0.78
Satin 4	1.74	1.67	1.37	1.62	1.51	1.21	1.51	1.43	1.00

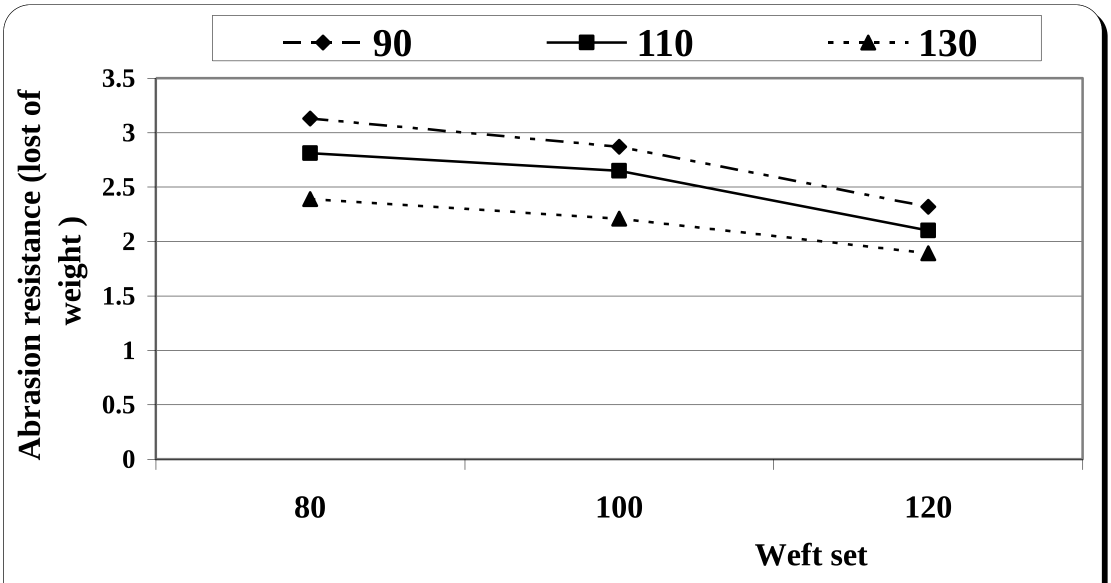

Fig (8) effect of warp and weft set on abrasion resistance (lost of weight), at denier 70 and satin 4

Table (17) regression equation and correlation coefficient for the effect of warp and weft set on abrasion resistance, (lost of weight), at denier ٧٠ and satin 4 .

Warp set	Regression equation	Correlation coefficient
90	Y =-0.0125X +3.41333	-0.9٨٧١٨٣٢٩
110	Y =-0.0١٧٧٥X +٤.٢٩٥	-0.9532133
130	Y =-0.0٢٠٢٥X +٤.٧٩٨٣٣	-0.979297

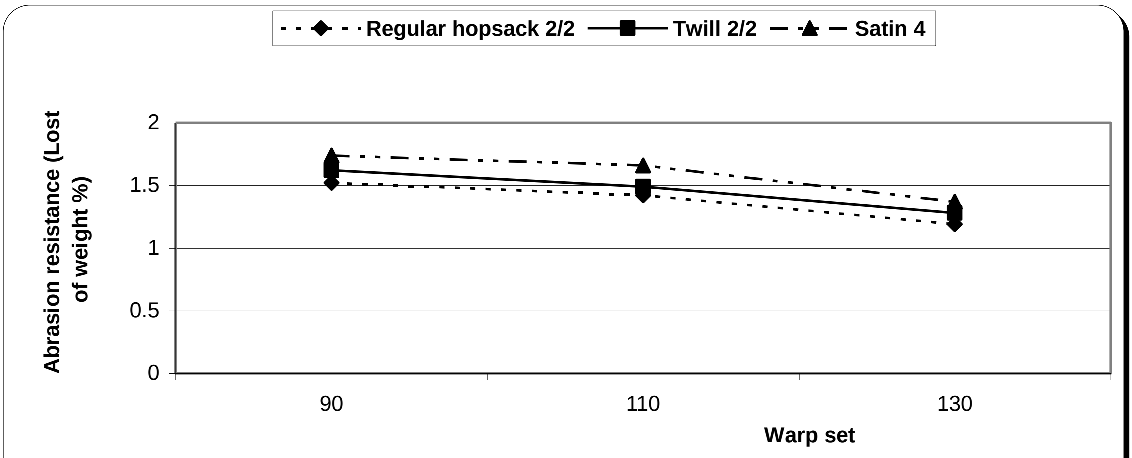

Fig. (9) effect of warp set and fabric structure on abrasion resistance ,at 80 pick/cm and 100 denier

Table (18) regression equation and correlation coefficient for the effect of warp set and fabric structure on abrasion resistance, (lost of weight), at denier ١٠0 and 80 pick/cm.

Fabric structure	Regression equation	Correlation coefficient
Regular hopsack 2/2	Y =-0.00825X +2.284167	-0.975097
Twill 2/2	Y =-0.0085X +0.398333	-0.990899
Satin 4	Y =-0.00925X +2.6075	-0.950281

It is obvious from the results 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, that there is a direct relationship between number of picks per cm and abrasion resistance. This is for the sake of that the increase in number of picks/cm cause fabrics to be more compacted leading to the increase in fabric abrasion resistance .

We can also notice that samples made of 70 denier have obtained the lowest rates of abrasion resistance , whereas samples made of 100 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.

Thickness

Table (19) results of thickness test applied to samples produced with denier 70.

The test	Thickness (mm)								
Number of picks/cm	**80**			**100**			**120**		
Warp set / Fabric structure	**90**	**110**	**130**	**90**	**110**	**130**	**90**	**110**	**130**
Regular hopsack 2/2	0.46	0.48	0.52	0.47	0.51	0.55	0.49	0.54	0.6 0
Twill 2/2	0.43	0.45	0.51	0.45	0.48	0.54	0.49	0.53	0.57
Satin 4	0.42	0.47	0.51	0.44	0.50	0.53	0.48	0.49	0.58

Table (20) results of thickness test applied to samples produced with denier 100.

The test	Thickness (mm)								
Number of picks/cm	**80**			**100**			**120**		
Warp set / Fabric structure	**90**	**110**	**130**	**90**	**110**	**130**	**90**	**110**	**130**
Regular hopsack 2/2	0.58	0.64	0.65	0.63	0.66	0.67	0.66	0.67	0.70
Twill 2/2	0.55	0.62	0.62	0.61	0.63	0.65	0.63	0.65	0.67
Satin 4	0.54	0.59	0.58	0.59	0.62	0.64	0.65	0.65	0.65

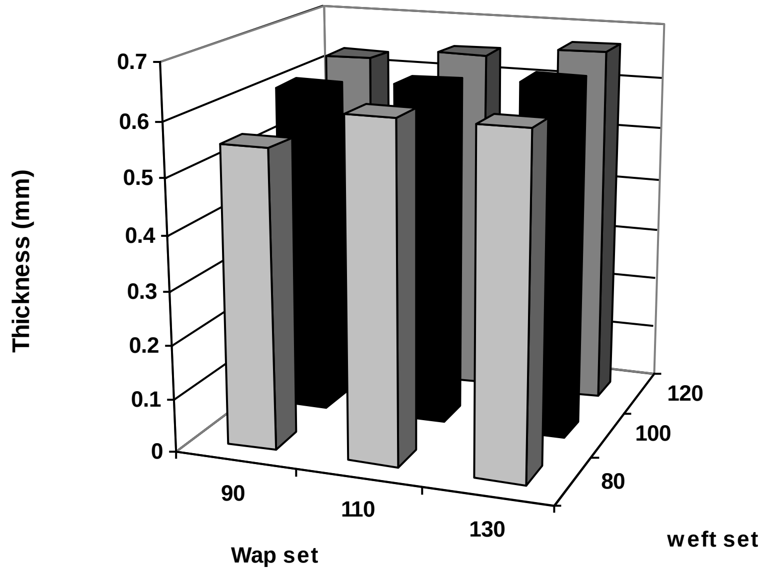

Fig (10) effect of warp and weft set on tensile strength, at denier 100 and twill 2/2

Table (21) regression equation and correlation coefficient for the effect of warp and weft set on thickness, at denier ١٠0 and twill 2/2.

Warp set	Regression equation	Correlation coefficient
90	Y =٠.0٠٢X +٠.39666	0.9٦٠٧٦٨
110	Y =0.00075X +0. 55833	0.98198
130	Y =0.00125X +0.521666	0.9٩3399

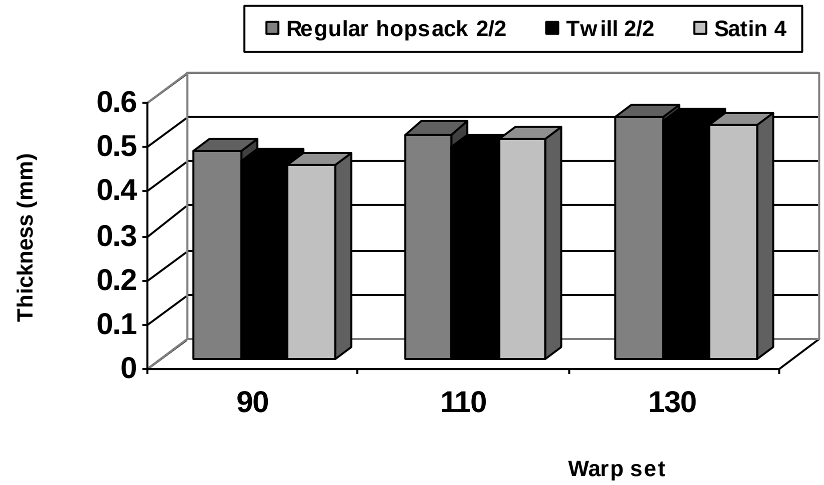

Fig. (11) effect of warp set and fabric structure on thickness, at denier 70 and 1000 pick/cm

Table (22) regression equation and correlation coefficient for the effect of warp set and fabric structure on thickness, at denier 70 and 100 picks/cm

Fabric structure	Regression equation	Correlation coefficient
Regular hopsack 2/2	Y =٠.٠٠٠٢X +٠.٢٩	١
Twill 2/2	Y =٠.٠٠٠٢٢٥X +٠. ٢٤٢٥	0.9٨١٩٨
Satin 4	Y =٠.٠٠٠٢٢٥X +٠.٢٣٩١٦٦٦	0.٩٩٧٩٤٨٧

It is clear from the diagrams, 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 , and it was found that the difference between both of them was insignificant. This is mainly for sake of that the 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 the other structures .

Another reason for these difference in thickness is yarn count, as samples with denier 100 have recorded the highest thickness followed by samples with 70 denier , This is due to that yarns of 100 denier are thicker than yarns of 70, 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 130 end per cm and 120 pick per cm have recorded the highest rates of thickness, whereas samples with 90 end per cm and 80 pick per cm have recorded the lowest rates.

Weight

Table (23) results of weight test applied to samples produced with denier 70

The test	Weight (g/m²)								
Number of picks/cm	80			100			120		
Warp set / Fabric structure	90	110	130	90	110	130	90	110	130
Regular hopsack 2/2	220.1	265.5	265.1	237.7	290.7	300.8	250.5	314.9	321.6
Twill 2/2	211.7	261.8	274.9	235.9	292.6	309	260.9	316.2	330.4
Satin 4	212.8	261.6	265.8	245.8	295.1	283.4	262.4	316.9	310.5

Table (24) results of weight test applied to samples produced with denier 100.

The test	Weight (g/m²)								
Number of picks/cm	80			100			120		
Warp set / Fabric structure	90	110	130	90	110	130	90	110	130
Regular hopsack 2/2	268.9	325.2	367.3	311.4	352.4	381.4	341.2	380.5	399.3
Twill 2/2	259.7	315.8	361.6	302.1	343.5	372.7	320.9	361.3	384.9
Satin 4	255.9	312.8	352.8	299.3	324.9	339.6	315.8	352.6	375.5

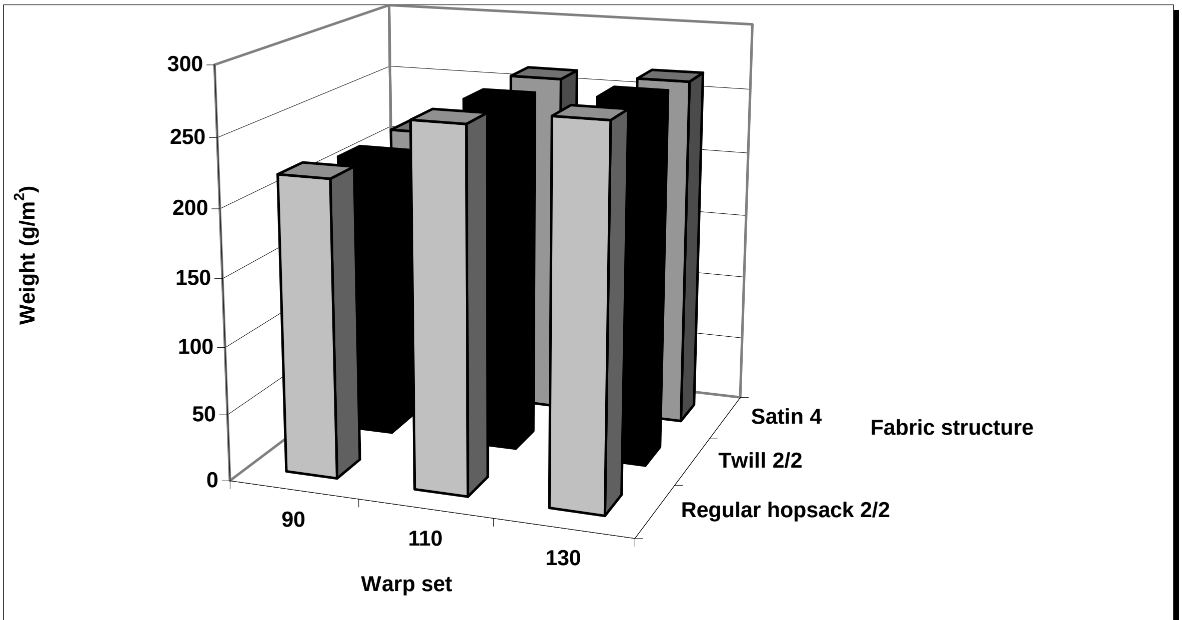

Fig. (12) effect of warp set and fabric structure on weight, at denier 70 and 80 pick/cm

Table (25) regression equation and correlation coefficient for the effect of warp set and fabric structure on weight, at denier 70 and 80 pick/cm.

Fabric structure	Regression equation	Correlation coefficient
Regular hopsack 2/2	Y =١.٣٢٥X +١٠٠.٤٨٣٣	0.٨٩٩٤٦١٧
Twill 2/2	Y =١.٤٥٥X +٨٧. ٧٥	0.9٢٣٠٨٤١
Satin 4	Y =١.٣٧X +١٠٢.٨	0.٩٣٥٠٠٦٥

It is clear from the diagrams that, the used structures did not give a significant effect on fabric weight as the differences between them were insignificant.

It is also clear that samples produced of 100 denier have recorded the highest weight, followed by samples with of 70 denier. This is due to that yarns of 100 denier are thicker than yarns of 70 (for the same unit area) , causing the produced samples to be increased in weight.

It was also found that the more yarns per unit area the more thicker the samples become, so samples with 130 end per cm and 120 pick per cm have recorded the highest weight , whereas samples with 90 end per cm and 80 pick per cm have recorded the lowest weight.

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