Study of the Thermal Isolation Range through Multilayered, Three Dimensional Composite Fabrics

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Abstract: There is no argument about that we have no way to reach the flow of progress and improvement in the field of technology of fabric design except by evolution and increasing the efficiency of our woven products performance and introducing adjustments if necessary to improve it and raising it to a level of quality control which is suitable and adequate its performance in service. There is no doubt that the field of fabrics has been so great that it could be used in all fields of our daily life to include medical field, aeronautics and protection of individuals and relieving them from surrounding bad-things in dangerous environments and critical work conditions. So, this study is considered a trail to set the scientific bases to design and produce new kinds of three dimensional fabrics composite with other materials to provide the produced fabric specifications to help thermal isolation a slight effect, by producing 36 samples of this kind of fabrics, using cotton and polyester as raw materials (fibers) blend together in various ratios. And also the production of fabrics of different densities of wefts per measuring unit (i.e.) (18, 20, 22) weft/cm. Also was produced fabrics with three different heights of pile between the two layers (i.e. heights of 0.5, 1, 1.5 cm). In addition, the space between the two layers was injected by rating material. After that, a test was performed to measure Thermal Isolation on these fabrics before and after injection process. Finally, test results were tabulated, and then were statistically analyzed, and finally relation drawings were made.

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Keywords: Warp (Vertical yarns); **Weft (**Horizontal yarns); **Count of yarn** (Yarn thickness); **Warp set (**Number of warp yarns per unit**); Weft set (**Number of weft yarns per unit)

1. Introduction

The important role that composite fabric construction installation play in the design of strategic properties of modern vital products, is generated by the extreme importance that is given by engineers and designers of modern products to fabrics and three-dimensional products which cannot be produced by using simple fabric structures (one warp with one group of wefts), but it needs composite fabric structures.

Three-dimensional fabric can be defined as those fabrics in which the thickness of the fabric represents considerable value exactly as the width of the weaving or its length represents [1]

That differs from woven fabrics composed of one group for (warp and weft) (as thickness of fabric does not represent considerable value compared with its length or its width). So it is right to call it two-dimensional fabric [2,3] .

We define the thermal insulation that resist heat flow is inversely proportional to the thermal conductivity [4] .

Air is considered a poor conductor of heat, so it is the best natural insulator, since its presence protects the wearer from the cold. On the other hand, it maintains the temperature of the body. In order to use air as a buffer must be confined and to make it stagnant is so stagnant air between the hairs, causing thermal insulation is required [5] .

The thermal conductivity of fabrics depends not only on an area of capillaries, consisting of fabrics, but also depends on the area of cross section of the pockets of stagnant air between fibers. And each of the capillaries and the air stagnant thermal conductivity is different, so the thermal conductivity of fabrics depends on the proportion of their volumes, in the fabric of the same class. In the case of multi-layered fabrics, the total thermal resistance is equal to the total thermal resistance of each layer separately [4] .

Different fibers in the fabric viability of the delivery of heat, wool, cotton is superior to the coefficient of thermal conductivity, and is therefore preferred as raw material for summer clothing, while the preferred raw material for winter is wool .

The thickness of the woven (i.e., the distance between the sides of the cloth) of the most important factors affecting the ability of the thermal insulation fabrics, the more thickness on The capacity of woven thermal insulation regardless of the type of fibers.

It also has conducted numerous experiments to determine the effect of fiber density and the type of fibers on the heat conductivity. Found that the type of yarns effect slightly [6] .

Where as the density of the fabric has a very important effect. Because we can increase the coefficient of thermal isolation to more than three times according to increase in density, but this coefficient increases only in a ratio (10% - 20%) as a result of the kind of fibers [7, 8] .

So the heat isolation materials except reflecting thermal isolation is specified with low apparent density and a reduced coefficient of thermal conduction because it contains a very big number of voids which contain air or gas which is distributed in different sizes and forms of the material.

The volume of air in some isolating material to nearly 70%, and may reach 99% of its total volume, which causes remarked reduction in the coefficient of thermal conduction of the material [5] .

The most important coefficients which affect the choice of suitable thermal isolation materials [9] .

1. Isolating material has a low coefficient of thermal conduction.
2. A high degree of resistance to water and ray leak.
3. A high degree of resistance to strains resulting from big differences temperature degrees.
4. A material having good mechanical properties, as high coefficient of compression resistance and high coefficient of break resistance.
5. Resistance to bacteria, rot and fire especially in places exposed to fire easily.
6. Giving no health harms.
7. Materials with fixed dimensions in the long range (having small coefficient of thermal elongation).
8. Resistance to chemical reactions.
9. Has a high degree of resistance to absorp water vapour.

2 .The experimental work:

Two kinds of textile materials were used in this research, cotton and polyester.

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

No	Property	Specification
1	Model	GUS KEN GMV-80
2	Kind of dobby	STAUBI 123.DE92
3	Let-off motion	Positive
4	Weave structure	(Double woven) warp pile (face to face)
5	Number of beams used	3 beams
6	Warp set (ends per cm)	16 end per cm
7	Number of pile yarns per cm	16 yarns per cm
8	Number of healds used	2 for pile, 2 for upper fabric and 2 for lower fabric.
9	Reed used (dents per cm)	8 dents per cm
10	Width of reed	139 cm

Table (2):The specifications of produced samples

Type of material	Type of pile material	Count of yarns	Weft set	Pile height
100% cotton (upper warp, lower warp and wefts)	100%cotton	20/2$^{(s)}$	18, 20, 22	0.5, 1, 1.5
100% polyester (upper warp, lower warp and wefts)	100% polyester	600/1 denier	18, 20, 22	0.5, 1, 1.5
100% cotton (upper warp, lower warp and wefts)	100% polyester	Cotton 20/2$^{(s)}$ polyester 600/1 denier	18, 20, 22	0.5, 1, 1.5
100% polyester (upper warp, lower warp and wefts)	100% cotton	Cotton 20/2$^{(s)}$ polyester 600/1 denier	18, 20, 22	0.5, 1, 1.5

Rating treatment of produced samples:

Fabrics treated with poly urethane.

Tests and analysis:

In this part, tests was carried out in order to evaluate the produced fabrics, this test was: the thermal insulation of fabrics were determined according to A.S.T.M. designations: D1518-85 (Re approval 1998) [10] .

3. Results and Discussion:

Results of experimental test carried out on the produced samples were presented in the following tables (3, 4) and graphs and were statically analyzed for statistically.

Table (3):The results of the thermal insulation test applied to produced samples (before treatment)

Fabrics specifications / Wefts per cm	100% cotton			70% cotton, 30% polyester			30% cotton, 70% polyester			100% polyester		
	Pile height (cm)			Pile height (cm)			Pile height (cm)			Pile height (cm)		
	0.5	1	1.5	0.5	1	1.5	0.5	1	1.5	0.5	1	1.5
18	0.357	0.621	0.842	0.391	0.685	0.956	0.469	0.797	1.05	0.498	0.821	1.24
20	0.424	0.664	0.886	0.457	0.761	0.998	0.507	0.869	1.12	0.573	0.892	1.32
22	0.478	0.716	0.922	0.496	0.822	1.04	0.579	0.906	1.17	0.623	0.989	1.39

Table (4):The results of the thermal insulation test applied to produced samples (after treatment)

Fabrics specifications / Wefts per cm	100% cotton			70% cotton, 30% polyester			30% cotton, 70% polyester			100% polyester		
	Pile height (cm)			Pile height (cm)			Pile height (cm)			Pile height (cm)		
	0.5	1	1.5	0.5	1	1.5	0.5	1	1.5	0.5	1	1.5
18	0.889	1.45	2.21	1.02	1.95	2.64	1.21	2.24	2.95	1.35	2.86	3.72
20	0.918	1.53	2.34	1.11	2.11	2.85	1.34	2.35	3.41	1.48	2.97	3.91
22	0.968	1.67	2.49	1.24	2.22	3.06	1.42	2.47	3.51	1.61	3.09	4.01

The pile height:

Figures (1, 2, 3 and 4) show that, there is an increasing relation between the height of pile and the ability of produced fabrics to insulate heat (all other executional specifications are constant) as result of increasing the thickness of fabrics according to the increase of the pile height. In addition to the increase of quantity of air existing between the two layers, that leads to increase the thermal insulation value.

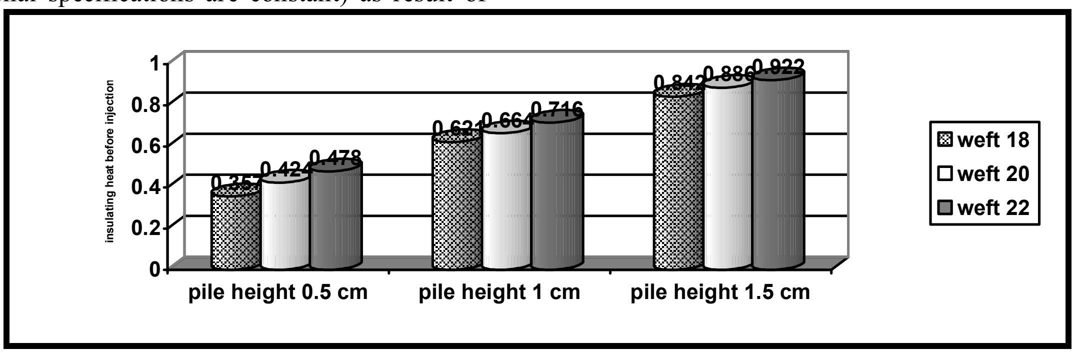

Fig. (1):Effect of pile height and number of picks/cm on thermal insulation for fabrics which produced from 100% cotton fibers (before treatment)

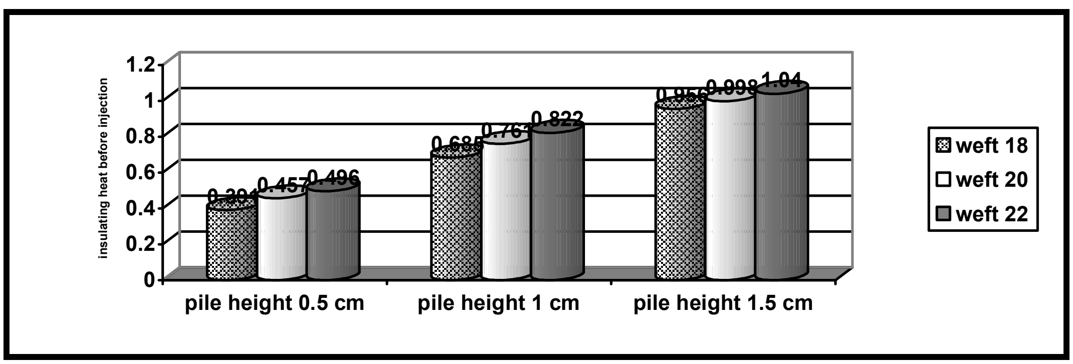

Fig. (2):Effect of pile height and number of picks/cm on thermal insulation for fabrics which produced from 70% cotton and 30% polyester fibers (before treatment)

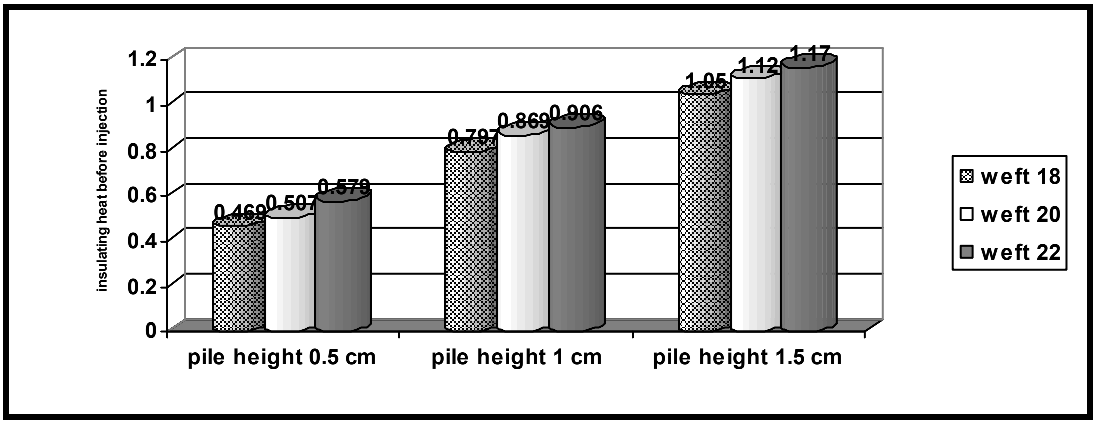

Fig. (3):Effect of pile height and number of picks/cm on thermal insulation for fabrics which produced from 30% cotton and 70% polyester fibers (before treatment)

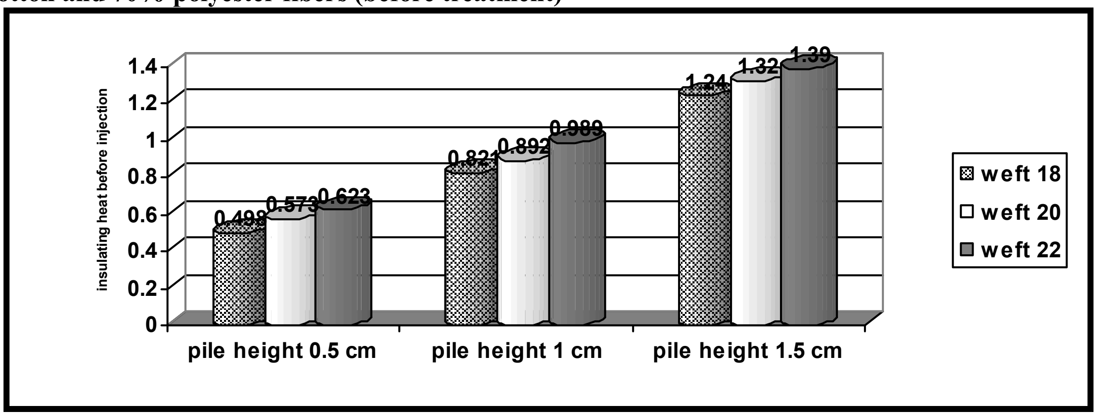

Fig. (4):Effect of pile height and number of picks/cm on thermal insulation for fabrics which produced from 100% polyester fibers (before treatment)

Picks per cm (weft set):

Tables (3, 4) and figures (5, 6, 7 and 8) containing the results of tests show that, there is an increasing relation between number of wefts per cm and the property of thermal insulation (all other executional specifications are constant) as a result of decreasing the number of air voids between wefts and other wefts. In according to the increase of the number of wefts/cm. That leads to decrease the quantity of lost heat, causing an increase the ability of produced fabrics to insulate heat.

Table (5):Regression equation and correlation coefficient for the effect of number of picks per cm and the ability of produced fabrics to insulate heat using 100% cotton fibers (after treatment)

Pile height (cm)	Regression equation	Correlation coefficient
0.5	Y = 0.0395 X + 0.846	0.9884
1	Y = 0.1100 X + 1.330	0.9878
1.5	Y = 0.1400 X + 2.0667	0.9991

Table (6):Regression equation and correlation coefficient for the effect of number of picks per cm and the ability of produced fabrics to insulate heat using 70% cotton and 30% polyester fibers (after treatment)

Pile height (cm)	Regression equation	Correlation coefficient
0.5	Y = 0.1100 X + 0.9033	0.9945
1	Y = 0.1350 X + 1.8233	0.9943
1.5	Y = 0.2100 X + 2.4300	1

Table (7):Regression equation and correlation coefficient for the effect of number of picks per cm and the ability of produced fabrics to insulate heat using 30% cotton and 70% polyester fibers (after treatment)

Pile height (cm)	Regression equation	Correlation coefficient
0.5	Y = 0.1050 X + 1.1133	0.9907
1	Y = 0.1150 X + 2.1233	0.9996
1.5	Y = 0.2800 X + 2.6967	0.9866

Table (8):Regression equation and correlation coefficient for the effect of number of picks per cm and the ability of produced fabrics to insulate heat using 100% polyester fibers (after treatment)

Pile height (cm)	Regression equation	Correlation coefficient
0.5	Y = 0.1300 X + 1.2200	1
1	Y = 0.1150 X + 2.7433	0.9996
1.5	Y = 0.1450 X + 3.5900	0.9843

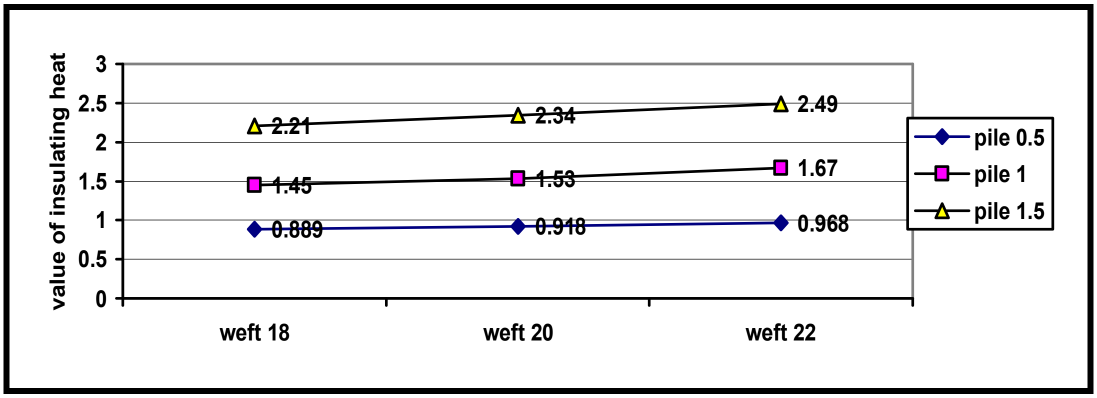

Fig. (5):Effect of number of picks/cm on thermal insulation for fabrics which produced from 100% cotton fibers (after treatment)

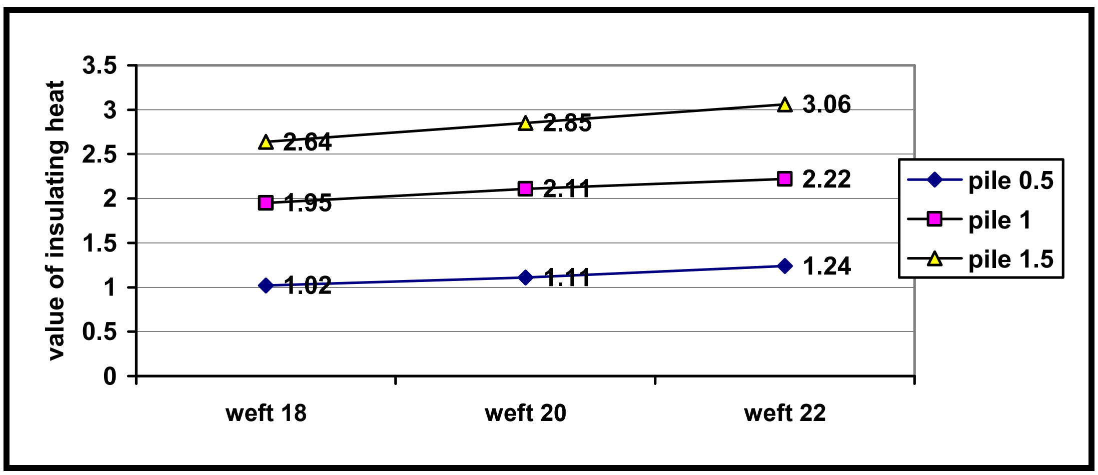

Fig. (6):Effect of number of picks/cm on thermal insulation for fabrics which produced from 70% cotton and 30% polyester fibers (after treatment)

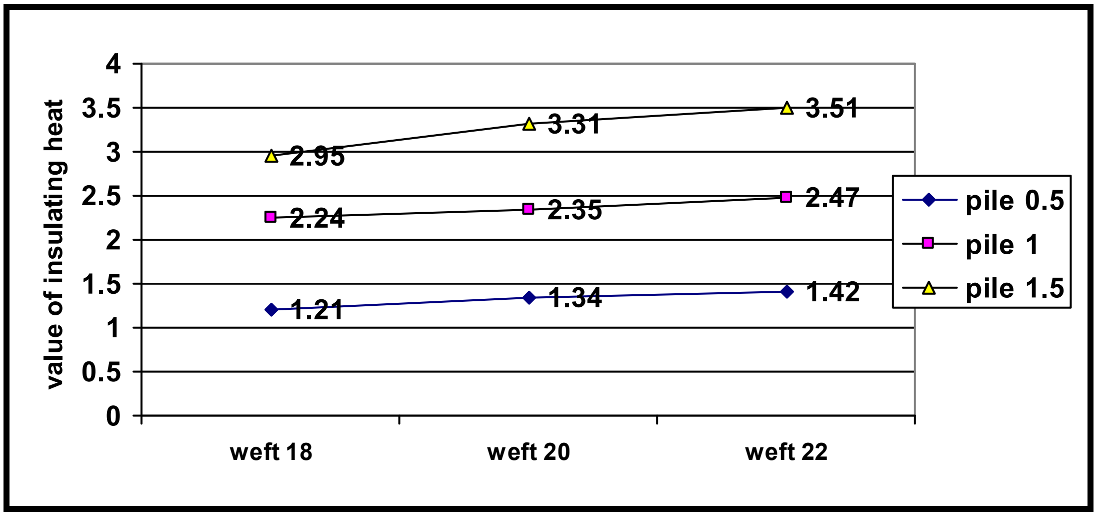

Fig. (7):Effect of number of picks/cm on thermal insulation for fabrics which produced from 30% cotton and 70% polyester fibers (after treatment)

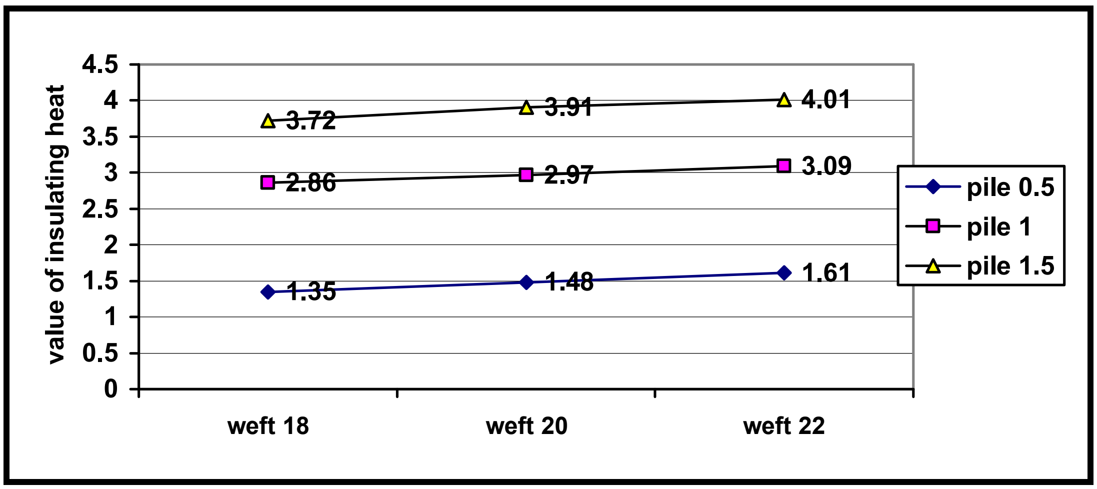

Fig. (8):Effect of number of picks/cm on thermal insulation for fabrics which produced from 100% polyester fibers (after treatment)

Difference in blending ratio between cotton and polyester fibers:

The study showed that, fabrics produced from 100% polyester fibers has verified highest readings for thermal insulation property, followed by fabrics produced from 70% polyester and 30% cotton fibers, after that fabrics produced in ratio 30% polyester and 70% cotton fibers, and lastly fabrics produced purely cotton which recorded the least readings (all other executional specifications are constant).

Treating fabrics with rating material:

Table (4) and figures (9, 10, 11 and 12) show an increase of the ability of produced fabrics to insulate heat after treating with the rating material (poly urethane) when compared with figures (1, 2, 3 and 4) which show the thermal insulation of the same kind of fabrics before rating treatment because the injection process leads to an increase in the thickness of the woven fabrics, and that related to preserving the air existing between the two layers which has an effective influence upon the property of thermal insulation, in addition to the natural of rating material which insulate heat (all other executional specifications are constant).

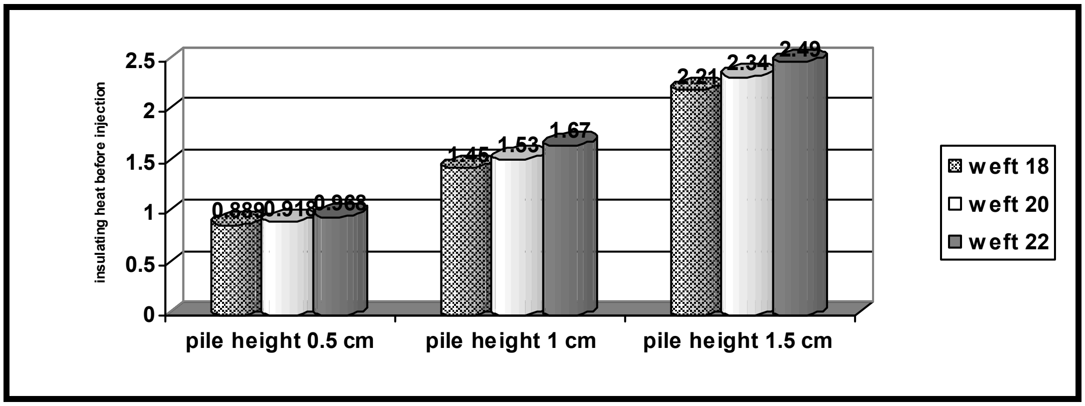

Fig. (9):Effect of pile height and number of picks/cm on thermal insulation for fabrics which produced from 100% cotton fibers (after treatment)

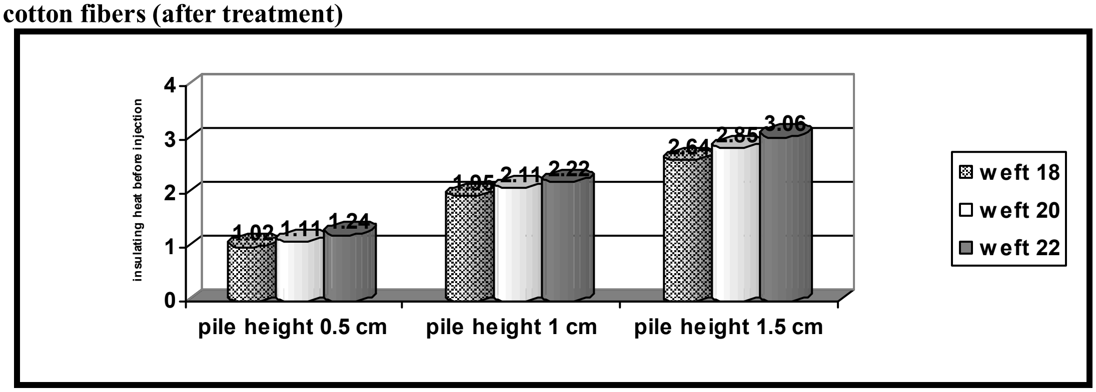

Fig. (10): Effect of pile height and number of picks/cm on thermal insulation for fabrics which produced from 70% cotton and 30% polyester fibers (after treatment)

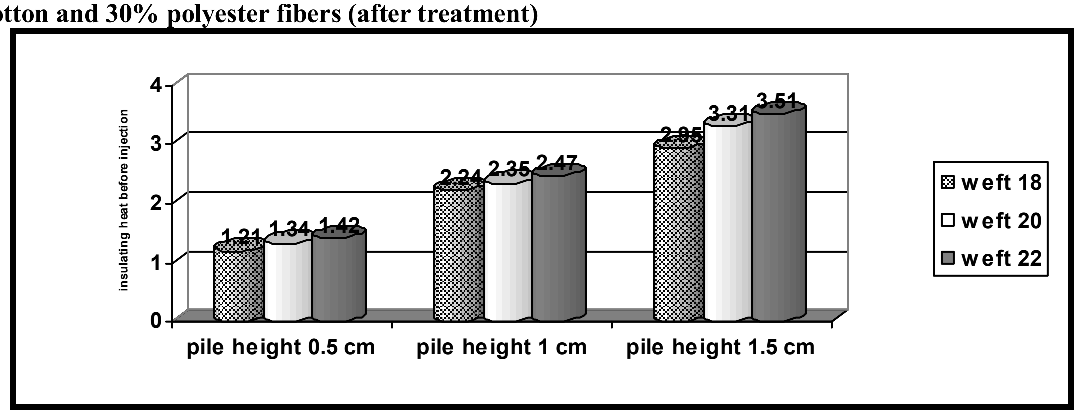

Fig. (11):Effect of pile height and number of picks/cm on thermal insulation for fabrics which produced from 30% cotton and 70% polyester fibers (after treatment)

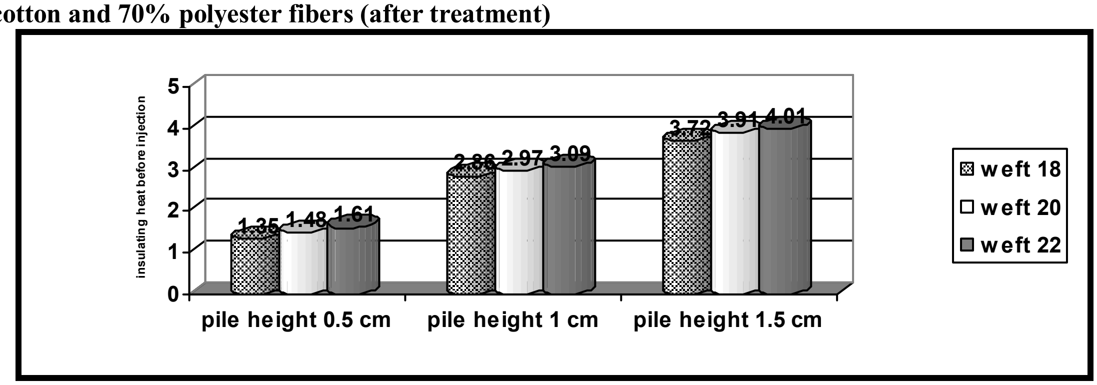

Fig. (12):Effect of pile height and number of picks/cm on thermal insulation for fabrics which produced from

100% polyester fibers (after treatment)

Table (9):The increase of the thermal insulation on percentages as a result of an injection process

Fabrics specifications / Wefts per cm	100% cotton			70% cotton, 30% polyester			30% cotton, 70% polyester			100% polyester		
	Pile height (cm)			Pile height (cm)			Pile height (cm)			Pile height (cm)		
	0.5	1	1.5	0.5	1	1.5	0.5	1	1.5	0.5	1	1.5
18	149.02	133.49	162.47	160.87	184.72	176.16	158	181.05	180.95	171.08	248.36	200
20	119.51	131.93	164.11	142.89	177.27	185.57	164.3	170.43	204.46	158.29	232.96	196.21
22	102.51	133.24	170.07	150	170.07	194.23	145.25	172.63	200	158.43	212.44	188.49

Conclusions

The study proved that there is an increasing relation between the height of pile and the ability of produced fabrics to insulate heat (all other executional specifications are constant).

There is a great effect from the difference in weft density (picks/cm) upon thermal insulation property. The study proved that there is an increasing relation between number of wefts/cm and the property of thermal insulation (all other

The difference of blending ratio between cotton and polyester fibers has an effective influence on the thermal insulation property. Fabric produced from 100% polyester fibers verified highest readings where as fabrics produced from 100% cotton fibers recorded the least readings concerning thermal insulation (all other executional specifications are constant).

The study assured that treating fabrics produced in the study with rating of poly urethane had a great effect to provide produced fabrics with new properties which helped in increasing the thermal insulation values compared with the values of the thermal insulation through the same fabrics before injection process or before treatment.

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