The Effect of using Multilayer Fabric in Controlling Water Permeability of some Protective Textiles

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Abstract:
Textiles are an essential component of the effective protection provided against many hazards such as chemicals, fire, and biological threats. When selecting a protective textiles, there are many factors to consider, such as the application type, level of protection, breathability, type of chemicals, cost, productivity, durability, and acceptance. In addition, textile design and the presence of air gaps, as well as textile's physical characteristics like thermal resistance, water absorption, and moisture transfer, play a significant effect. This research presents a study concerning using multi-layer fabrics as a factor for controlling the water permeability of some protective fabrics.

Keywords:
Technical Textiles, Protective Textiles, Water Permeability, Multilayer Fabrics.

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1. Introduction:

Technical Textiles:

Technical textiles represent the fastest increasing section in the clothing and textile industries, it can be seen as high added value applications [1].

Technical textiles are differentiated from other textiles in that they are made or designed to have specific functional properties and technical performance, rather than having decorative or aesthetic properties [2], [3].

Technical textiles can be referred to as functional textiles, industrial textiles, engineering textiles, performance textiles, and hi-tech textiles. Technical textiles may be used individually or as a part of another product to improve the product performance. Technical textiles are used as accessories in processes to make other products as paper maker felt in paper mills or filter textile in food industry[4].

Technical textiles provide several functions as liquid repellence, absorbency, stretch, resilience, strength, softness, washability, flame resistance, microbial barrier, filtering etc. these properties are mostly combined to create textiles suited for specific applications.

Depending on the product functional requirements, properties, and end-user applications, the highly diversified of technical textile products have been divided into the following: hometech, packtech, sporttech, medtech, clothtech, indutech, geotech, agrotech, oekotech, buildtech, mobiltech, protech [5].

Protective Textiles:

The value and quality of human life have undoubtedly increased as a result of scientific advances in a variety of sectors. However, it should be acknowledged that technological advancements have also exposed us to threats and the danger of being affected by unidentified physical, chemical, and biological attacks. We also continue to be exposed to hazards from radiation, chemicals, fire, and biological threats like viruses and bacteria.

Textiles are an essential component of the effective protection provided against the majority of these hazards.

Today's hazards which we are exposed to are often so specialized that no one type of clothing would provide enough protection.

Protective clothing must provide appropriate protection, and should be comfortable to wear. Predicting the performance and comfort of clothing depends on the clothing design, appropriate material selection, and final evaluation of the results [6], [7].

Protective Textiles Classification:

Categorizing protective textiles is a challenging due to no single classification can clearly describe all types of protection. Overlapping of definitions is common since there are so numerous professions and applications, even the same class of protective clothing frequently has different requirements in method and protection. According to the end-use functions, protective textiles can be categorized into categories like electrostatic protection, thermal protection, flame protection, chemical protection, biological protection, radiation protection, mechanical impact protection, and wearer visibility, etc.[8].

Water Permeability:

water permeability is one of the most essential properties, which affects the thermal insulation, quick liquid absorption, ability to evaporate water while remaining dry to the touch, and transporting perspiration from the skin to the outer surface and then quickly dispersing it. The term permeation test is refer to the penetration of Water / Liquids through a textile material at a molecular level.

Liquid permeability is vital in textiles, especially when used for protection against water-related hazards. Liquid permeability is an outstanding technical characteristic that is highly required in textile materials utilized in different sectors ranging from biosciences, electronics, sports, industries, and other active wear. This extends beyond only water permeability to include other liquids such as alcohols, inks, and oils, which are commonly used in various sectors [9], [10].

Multi-layer Fabric:

Multilayer fabric is a type of fabrics which are composed of one or more layers. Multilayered fabrics may consist of various layers of the fabrics which have the ability to complement and enhance the essential comfort [11], [12]. The method of production, fabric structure, materials and weight of each layer can be controlled according to the final usage and required properties. Number of layers could play a significant role in moisture and heat transport properties of fabrics. [13], [14].

A good multilayered system should include at least three layers: outermost layers, and an inner layer[15].

2. Experimental:

Fabric Production:

The excuted fabrics were multi-layer fabrics that consists of woven fabrics for the outer 2 layers and non-woven fabrics for the filling layer.

Woven Fabric Produced Specifications:

Four materials were used in the six produced woven fabrics as shown in table 1:

Two looms were utilized to produce the fabrics, loom 1 with a cotton warp, and loom 2 with a polyester warp.

Table (1): Types of Produced Fabric

Serial	Type	Warp material	Weft material
1	Cotton	Cotton 100%	Cotton 100%
2	Polyester	Polyester 100%	Polyester 100%
3	Cotton – Acrylic	Cotton 100%	Acrylic 100%
4	Cotton – Viscose	Cotton 100%	Viscose 100%
5	Polyester – Cotton	Polyester 100%	Cotton 100%
6	Polyester – Acrylic	Polyester 100%	Acrylic 100%

Yarn Count:

Cotton 80/2 Ne (266/2 Denier) was utilized for warp yarns of loom 1, and polyester 150/1 Denier (36/1 Ne) was utilized for warp yarns of loom 2.

30/1 Ne (177/1 Denier) was utilized for weft yarns.

Fabric Set:

All woven fabrics have the same number of warp, which were 66 ends per cm, and the same number of picks, which were 30 picks per cm.

Fabric Structure:

Canvas 2/2 structure was utilized to produce the fabrics.

Nonwoven Fabric Produced Specifications

Polypropylene was utilized for producing nonwoven fabrics.

Nonwoven fabrics weight is 110 gm/m².

Nonwoven fabrics were produced by thermal bonding process, these utilized as filling (Middle) layer.

Bonding Process:

Stitching method was used to bond the layers to produce multi-layer fabrics. Single needle sewing machine was utilized to bond the layers as shown in figure 1.

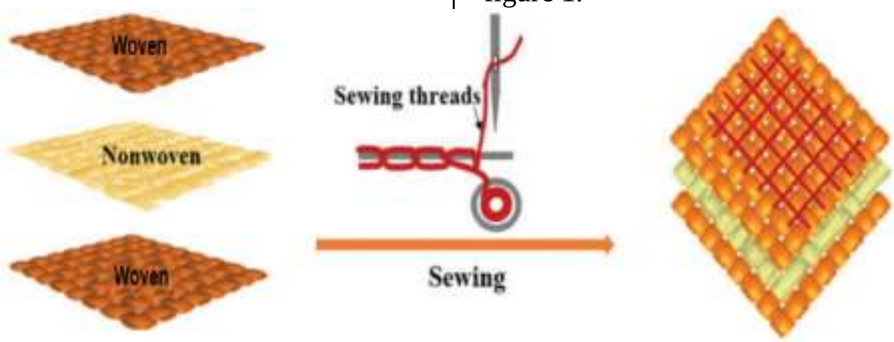

Figure (1) Bonding the Fabric Layers [16]

Polyester yarn (210/3 denier) was utilized for sewing.
Sewed squares were formed by the size of, 3x3 cm, 4.5x4.5 cm, and 6x6 cm.

Stitching design of multilayer fabrics is shown in figure (2):

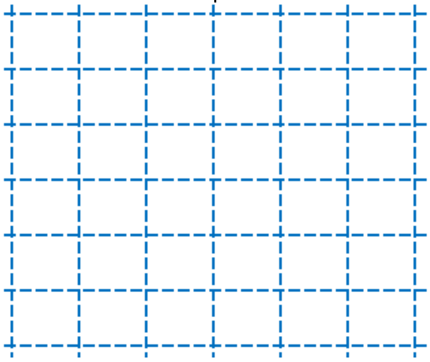

Figure (2) Stitching Design of Multilayer Fabrics

Layering Process:

Samples were prepared utilizing three layers of fabric (Sandwich): two outer layers (woven fabric) and one filling layer (nonwoven fabric), bonding them by stitching at different distances, 3 cm, 4.5 cm, and 6 cm.

Multi-layer fabrics arrangement is shown in table (2):

Table (2): Types of Produced Multilayer Fabric

Serial	Outer layer	Filling layer	Outer layer
1	Cotton	Polypropylene	Polyester
2	Cotton		Polyester - Cotton
3	Cotton		Cotton – Acrylic
4	Polyester		Polyester - Cotton
5	Polyester		Cotton - Viscose
6	Polyester		Cotton - Acrylic
7	Polyester		Polyester - Acrylic

Fabric Testing:

Fabric thickness test, was carried out according to the standard method ASTM D 1777 [17].

Fabric water permeability test, was carried out according to the standard method ASTM D 4491 [18].

3. Results and Discussion:

This section are divided into three sub-sections. In Section 3.1., results and discussion for fabric thickness test. In Section 3.2., results and discussion for fabric water permeability test. In Section 3.3., discussion for the effect of fabric thickness on water permeability.

3.1. Fabric Thickness:

Table (3) and figure (3) represent the change of the different of stitching distances on fabric thickness of produced fabrics.

Table (3): The Effect of the Changing of Stitching Distances on Fabric Thickness for Produced Fabrics

Samples		6x6 cm	4.5x4.5 cm	3x3 cm
		(Cm³/Cm²/S)		
Outer Layer	Cotton	1.97	1.92	1.855
Filling	Polypropylene			
Outer Layer	Polyester			
Outer Layer	Cotton	1.981	1.908	1.848
Filling	Polypropylene			
Outer Layer	Polyester - Cotton			
Outer Layer	Cotton	2.012	1.931	1.86
Filling	Polypropylene			
Outer Layer	Cotton – Acrylic			
Outer Layer	Polyester	1.964	1.868	1.818
Filling	Polypropylene			
Outer Layer	Polyester - Cotton			
Outer Layer	Polyester	2.03	1.925	1.866
Filling	Polypropylene			
Outer Layer	Cotton - Viscose			
Outer Layer	Polyester	1.952	1.891	1.837
Filling	Polypropylene			

Outer Layer	Cotton – Acrylic			
Outer Layer	Polyester	1.956	1.914	1.825
Filling	Polypropylene			
Outer Layer	Polyester - Acrylic			

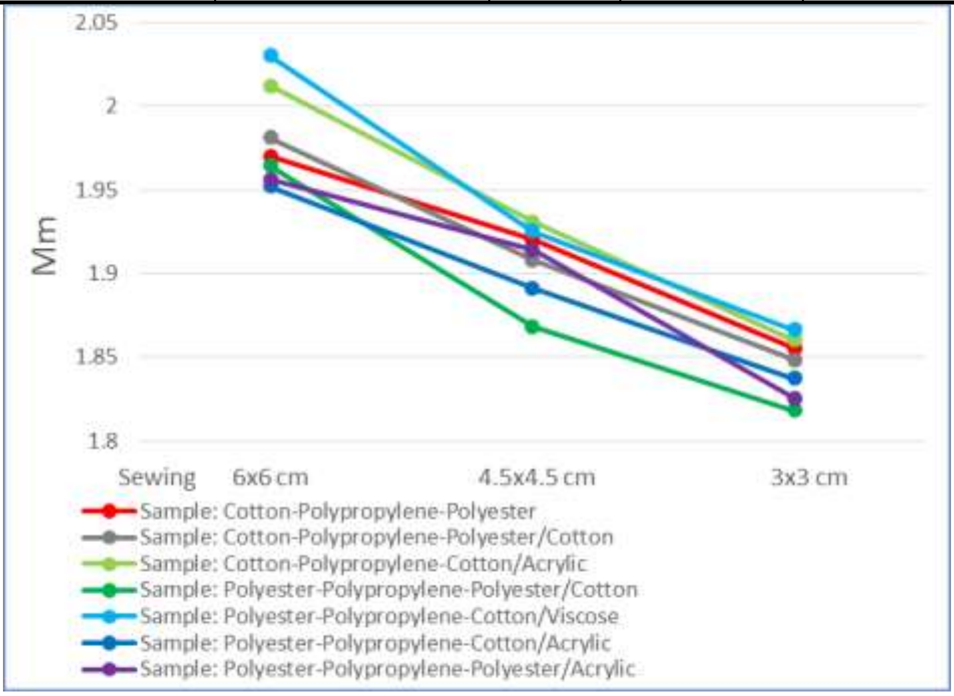

Figure (3): The Relationship between Different Stitching Distances and Fabric Thickness for Produced Fabrics

As shown in table (3) and figure (3) which represent the relationship between bonding fabric layers by stitching method at different distances & the different materials of outer layers and fabric thickness for produced fabrics, it is clear that there is an increase in the fabric thickness for both samples 4.5x4.5 cm and 6x6 cm respectively. The different materials of outer layers did not show a remarkable significant effect.

3.2. Fabric Water Permeability:

Table (4) and figure (4) represent the effect of the different of stitching distances and outer layers materials on fabric water permeability for produced fabrics.

Table (4): The Effect of the Changing of Stitching Distances on Fabric Water Permeability for Produced Fabrics

Samples		6x6 cm	4.5x4.5 cm	3x3 cm
		(W/Cm*C)		
Outer Layer	Cotton			
Filling	Polypropylene	0.29	0.31	0.37
Outer Layer	Polyester			
Outer Layer	Cotton			
Filling	Polypropylene	0.25	0.28	0.35
Outer Layer	Polyester - Cotton			
Outer Layer	Cotton			
Filling	Polypropylene	0.18	0.22	0.28
Outer Layer	Cotton – Acrylic			
Outer Layer	Polyester			
Filling	Polypropylene	0.42	0.57	0.64
Outer Layer	Polyester - Cotton			
Outer Layer	Polyester			
Filling	Polypropylene	0.31	0.37	0.39
Outer Layer	Cotton - Viscose			
Outer Layer	Polyester	0.33	0.38	0.44
Filling	Polypropylene			

Outer Layer	Cotton – Acrylic			
Outer Layer	Polyester	0.58	0.67	0.72
Filling	Polypropylene			
Outer Layer	Polyester - Acrylic			

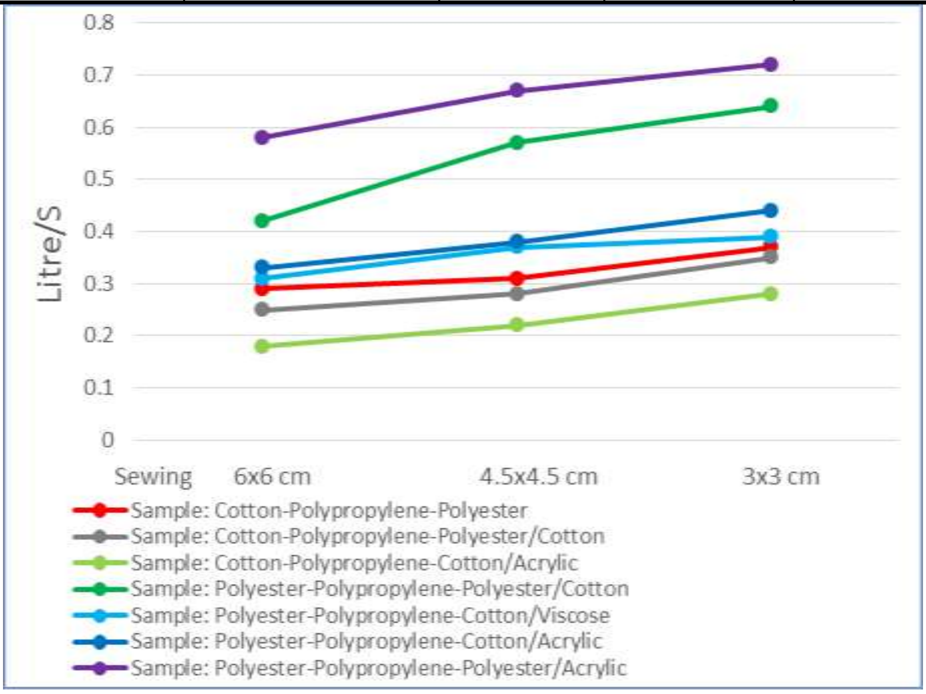

Figure (4): The Relationship between Different Stitching Distances and Fabric Water Permeability for Produced Fabrics

From table (4) and figure (4) which represent the relationship between bonding fabric layers by stitching method at different distances and fabric water permeability for produced fabrics, it is clear that samples 3x3 cm generally are a bit higher than its counterpart samples 4.5x4.5 cm, and samples 4.5x4.5 cm are a bit generally higher than its counterpart samples 6x6 cm. Sample of (polyester-polypropylene-polyester/acrylic) with stitching 3x3 cm has the highest value for fabric water permeability, and sample (cotton-polypropylene-cotton/acrylic) with stitching 6x6 cm has the lowest value for fabric water permeability.

it is clear from the above figure that there is an increase in the fabric water permeability for both samples 4.5x4.5 cm and 3x3 cm respectively, this is may be due to that using sewing threads for stitching larger squares leads to create larger air gabs between fabric layers that acts as a barrier against water transmission, results in to decrease in fabric water permeability.

3.3. The Relationship between the Fabric Thickness and Fabric Water Permeability for Produced Fabrics:

From fabric thickness results and water permeability test results, it is clear that samples 3x3 cm has lower thickness and higher water permeability than its counterpart samples 4.5x4.5 cm. Also samples 4.5x4.5 cm has lower thickness results and higher water permeability than its counterpart samples 6x6 cm, this means that the thickness of the fabric has an effect on fabric water permeability.

Conclusion:

This study investigated the effect of bonding fabric layers by stitching at different distances on the water permeability of fabrics with different materials.

From the results, the following conclusions can be reached:

- Fabric thickness influencing water permeability, and is inversely proportional to it.
- Multilayer fabrics which include polyester yarn in both of their outer layers have the highest values for fabric water permeability, this may be due to poor absorbency of polyester to water, as the hydrophobic character of polyester causes water to transmit by capillary channels.
- There is an increase in the fabric water permeability for both samples 4.5x4.5 cm and 3x3 cm respectively, this is may be due to using larger squares which create larger air gabs between fabric layers that acts as a barrier against water transmission and results in decreasing in fabric water permeability.

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