Improvement of the Properties of Multi-Layered Fabrics Used in the Production of Mattresses to Achieve the Best Functional Performance

Prof. Ehab Haidar Shirazi
Prof. Textile Dept., Applied Arts, Helwan University
Prof. Mohamed Abdel Gawad
Prof. Textile Dept., Applied Arts, Helwan University
Marwa Mostafa qotb
Instructor. Textile Dept., Applied Arts, Helwan University

Abstract:
Sleep is a vital and a basic activity of human life and it is a physiological need for human body. Sleep quality is directly influenced by the comfort conditions of sleep environment. The purpose of this research is to define the role of textile materials and weave structure used in quilted fabrics to achieve the best functional performance from the human body.
Thermal transmittance, thermal conductivity, thermal resistance, thickness, tensile strength, wicking and air permeability properties of fabrics were analyzed and statistically evaluated.
Comfort is a major concept in the determination of overall life quality as well as sleep quality of a resting person. Therefore academic studies about thermal comfort prediction of sleep environment and bed surface fabrics are of great importance. This study investigates conventional mattress ticking fabrics in terms of comfort parameters and defines the important fabric properties on comfort parameters.
The use of mattresses varies widely both in common use in the homes of various sizes , hotels, care homes or (nursing homes) and hospitals, which requires a different set of properties, depending on the functionality of each of them as he does not hide the importance of using medical mattresses because of their therapeutic benefits.

Keywords:
Multi layered Fabric
Comfort
Thermal transmittance
Wicking
Air permeability

Paper received 17th July 2017, Accepted 13th September 2017, Published 1st of October 2017

1. Introduction
Multilayered fabrics consist of different layers of the fabrics which have the ability to complement and maximize the essential comfort properties for a specific end use "mattress fabric". Presence of more number of layers can reduce pressure, temperature; shear and friction developed on body and also enhance the moisture absorbency and moisture vapor transport property. The comfort properties such as air permeability, water absorbency, wettability, wicking, water vapor permeability and thermal conductivity of multilayered. (1)

1.1. Upholstery layers (Comfortable Layers)
Mattress fabrics or just plain “ticking”, the textiles used to upholster mattresses and foundations are a vital part of the marketing and the comfort and performance of today’s bed sets. (2)
The middle upholstery comprises all the material between the insulator and the quilt. It is usually made from materials which are intended to provide comfort to the sleeper.
The comfort layer as shown in figure (1) is divided into three subcategories:
1- The insulating layer.
2- The Middle upholstery layer or (cushioning layer).
3- The multi layered fabrics (The quilt or Ticking layer).(3)

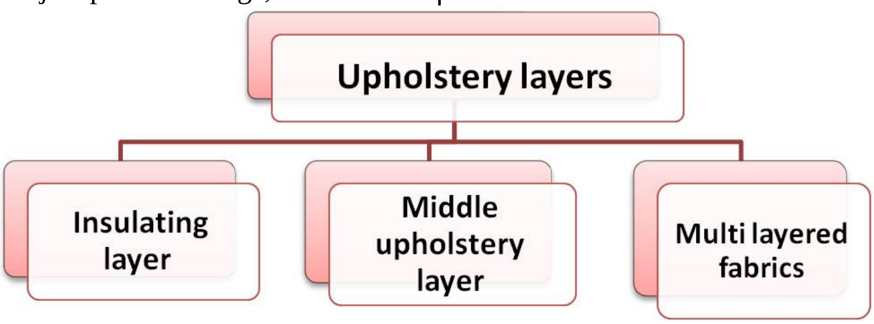

Figure (1) Comfortable Layers

1.2. Insulating layer

The insulating layer is the first layer next to the innerspring unit. It forms a barrier between the softer foam layers to reduce the likelihood of them "pocketing" into the spring unit and causing a lumpy uncomfortable sleeping surface. The insulating layers prevent the springs from penetrating the upper layers of the mattress are made from a fiber batting or layers of non-woven fabrics are shown in figure (2). [4]

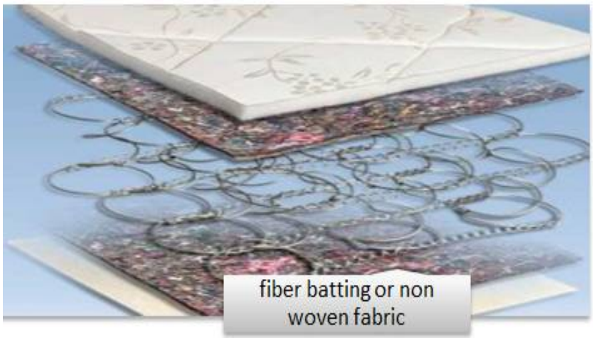

Figure (2) Mattress cross-section

1.3. Middle upholstery layer (cushioning layer)

The middle upholstery layer provides an extra layer of comfort, and may include flat or convoluted PUF as shown in figure (3), shredded pads of compressed polyester, or fiber battings. The insulator and cushioning layers can be stacked in varying sequences between the quilt and the innerspring support. [3]

1.4. Multi layered fabrics (Quilt layer)

The quilt is the top layer of the mattress. It provides a soft surface texture and a level of firmness that can be varied by changing the material and the details of construction. The quilt consists of the ticking plus low-density foam or fiber batting that is stitched to its underside. These two layers are sewn to a tape edge that attaches to the border quilting around the perimeter of the mattress. [3]Multi layered mattress fabrics comprises from three layers as shown in figure (4).

1- Top layer (woven fabric or knitting fabric).
2- Inner layer (Nonwoven fiber pad).
3- Bottom layer (woven fabric or Nonwoven fabric).

Figure (3) Middle upholstery layer and convoluted PUF

1.5. The Functional properties of Multi layered Fabric

Comfort can be divided into three groups, psychological, tactile and thermal comfort. Psychological comfort is mainly related to the aesthetic appeal.

Tactile comfort has a relationship with fabric surface and mechanical properties.

Thermal comfort is related to the ability of fabric to maintain the temperature of skin through transfer of heat and perspiration generated with the human body. [5]

The physical and mechanical properties of these fabrics are affected by the fiber type, yarn construction and fabric structure, as well as any treatment that may have been applied to the materials. A range of fabric performance parameters are assessed for different end-use applications. [48] Comfort properties of any textile fabric it is necessary to be able to measure some physical properties of the fabric itself. The factors that can affect the comfort performance are the heat transfer and the movement of moisture between the human body and the environment; in order to take into account these effects some physical test can be done in order to evaluate the following properties:

***Figure (4)** Multi layered fabrics (Quilt layer)*

- Air permeability
- Thermal properties

- Liquid moisture transmission
- Moisture vapour transmission [5]
- Fabric Weight and thickness
- Warp and weft yarn linear density

The thickness of a fabric is one of its basic properties, giving information on its warmth, weight and stiffness.[6]

2. EXPERIMENTAL WORK

This research is improving the properties of multi-layered fabrics used in the production of mattresses to achieve the best functional performance (Fabric Weight, thickness, air Permeability, thermal transmittance)

2.1. Specifications of machine used in producing the fabric

The specification of machine used in producing the fabric as shown in table (1).

Table (1) Specifications of machine used in producing the fabric

NO	Item Details	Specification
1	Loom Name	Itema
2	Loom Model	R9500
3	Manufacturing Country	Italy
4	Manufacturing Year	2014
5	Loom Type	Rapier
6	Loom Width(Reed Width)	190 cm
7	Reed used (dents per cm)	9 dents/cm
8	Denting	4 ends / dent
9	Ends /cm	36 yarns
10	Width of Warp without selvedge	161.1 cm

2.2. The Parameters Used for Producing the Samples under Study

In this research 12 fabrics were produced according to table (2) each fabric contains different Weave structure, Weft material of upper layer and Weight for padding layer.

The Multi layered Fabric consists of three layered (top layer Woven fabric (produced fabrics), Inner layer (100% polyester non-woven wadding) and Bottom layer (nonwoven fabric).This three layered is stitched together for making the multilayered (three-layer) fabric assemblies.

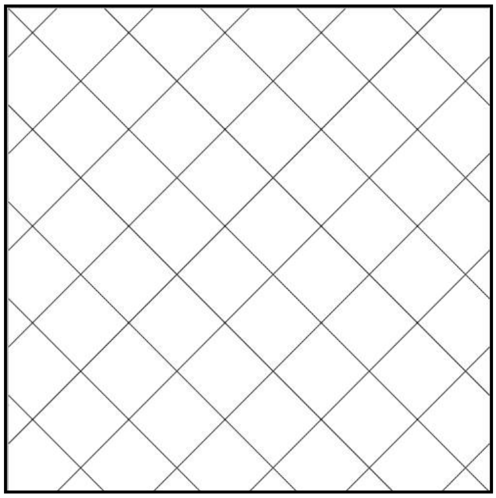

Figure (5) Stitching Design of Multi layered fabric

Table (2) the specifications of Multi layered produced samples

Sample No	Top layer		Inner layer	Bottom layer
	Fabric warp/weft material	weave Structure of fabrics		
1	Cotton/cotton	Satin	Weight 1	weight of Nonwoven fabric =22 gm/m2
2		Satin	Weight 2	
3		Honeycomb	Weight 1	
4		Honeycomb	Weight 2	
5	Cotton/viscose	Satin	Weight 1	
6		Satin	Weight 2	
7		Honeycomb	Weight 1	
8		Honeycomb	Weight 2	
9	Cotton/polyester	Satin	Weight 1	
10		Satin	Weight 2	
11		Honeycomb	Weight 1	
12		Honeycomb	Weight 2	

Weight 1: One layer fiber pad : **(160 gm/m^2)**
Weight 2: Double layer fiber pad: **(320 gm/m^2)**

2.2.1. The specifications of the produced fabrics (Top layer)

1-Material of warp: Cotton. 2- Count of the warp: 50/2 Ne.
3-No. of warp: 36 yarns /cm.
4-Material of weft: Cotton, viscose, polyester

- Count of the Cotton weft 30/2 English, No. of weft 24 pick /cm.
- Count of the Viscose weft 30/2 English, No. of weft 24 pick /cm.
- Count of the Polyester weft 300/288 denier, No. of weft 24 pick cm

(288) Number of fibers in cross section.

2.2.2. Fabric structures

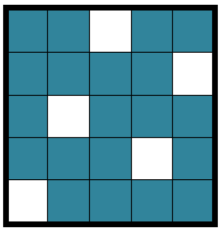

Figure (6) Satin 5

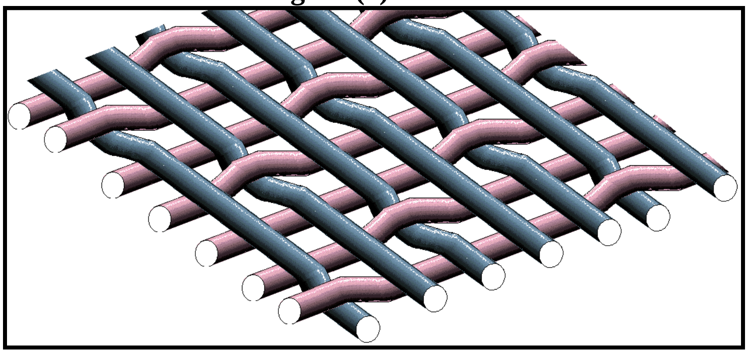

Figure (7) Simulation for satin weave

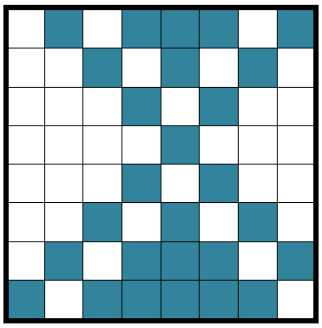

Figure (8) Honeycomb weaves 8

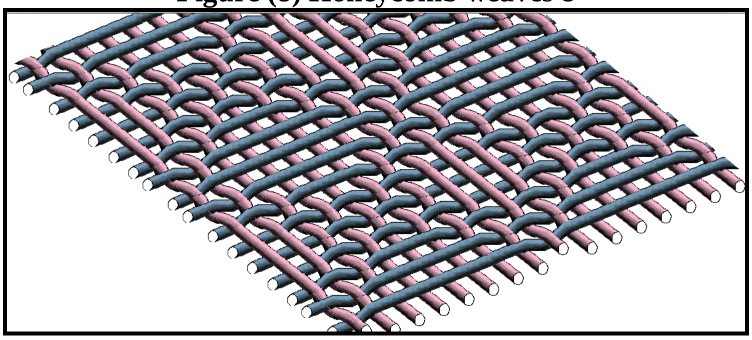

Figure (9) Simulation for Honey Comb weaves

2.3. Laboratory Tests Applied to Samples under Study

2.3.1. Fabric Weight Test

This test was carried out according to the American Standard Specification of (ASTM-D-3776-79). [7]

2.3.2. Fabric Thickness Test

This test was carried out by using Mituoyo thickness digital gage no. 7301 produced by Turlock Japan company according to the American Standard Specification of (ASTM-D-1777-1996).[8]

2.3.3. Fabric Thermal Transmittance Test

ASTM D: 1518 Standard Test Method for Thermal Transmittance of Textile Materials by Tog-meter unit. ([9]

2.3.4. Fabric Air Permeability Test

This test was carried out by using The Digital Air Permeability Tester M021A (SDL ATLAS) according to the American Standard Specification of (ASTM-D737-04(2012)). [10]

3. RESULT AND DISCUSSION

The produced fabrics in this research were tested for some essential functional properties which reflected to their end uses.

Table (3) Test results of produced multi-layered fabrics

Sample No	Fabric material	Structure of fabric	Inner layer	Thermal transmittance (Tog)	Air permeability (l/m2/sec)	Fabric thickness (mm)	weight gm/m^2
1	cotton	Satin	Weight 1	5.12	276	4.57	361
2		Satin	Weight 2	3.41	363	8.24	521
3		Honeycomb	Weight 1	8.94	407	3.86	363
4		Honeycomb	Weight 2	4.52	435	7.74	523
5	viscose	Satin	Weight 1	5.61	405	4.5	382
6		Satin	Weight 2	3.65	426	7.87	542
7		Honeycomb	Weight 1	9.43	479	4.23	387
8		Honeycomb	Weight 2	5.54	501	7.84	547
9	polyester	Satin	Weight 1	5.48	276	5.56	373
10		Satin	Weight 2	3.5	308	9.11	533
11		Honeycomb	Weight 1	9.32	421	3.61	432
12		Honeycomb	Weight 2	4.92	470	8.91	592

Structure A: (Satin weave 5)
Structure B: (Honeycomb weave 8)
Weight 1: One layer fiber pad (160 gm/m^2) **Weight 2 : Double layer fiber pad (320 gm/m^2)**

In the produced sample, proper arrangements were made to create a multilayered fabric assembly with three fabric layers (top, middle and bottom) and two air gaps in between the fabric layers , (top, two layer in middle and bottom) and three air gaps in between the fabric layers.

3.1.1 Weight of Multi-layered fabric

Table (4) and figure (10) show the results of weight test for different materials, different structure and different weight of fiber pad in samples.

Table (4) Results of multi-layered fabric Weight Test (gm /m^2)

structure	cotton		viscose		polyester	
	weight 1	weight 2	weight 1	weight 2	weight 1	weight 2
structure A	361	521	382	542	373	533
structure B	363	523	387	547	432	592

As observed from the Table (4) and figure(10), the highest fabric weight in sample no (12) and sample no(1) the lest weight, due to the weight of the wadded layer in sample no(1)the weight of wadded layer 160gm/m^2 and sample no(12)the weight of the wadded layer 320gm/m^2. There is a positive relationship between the ratio of the wadded nonwoven fiber pad and the fabric weight. Therefore, the fabrics weight increase as well as the ratio of the wadded layer.

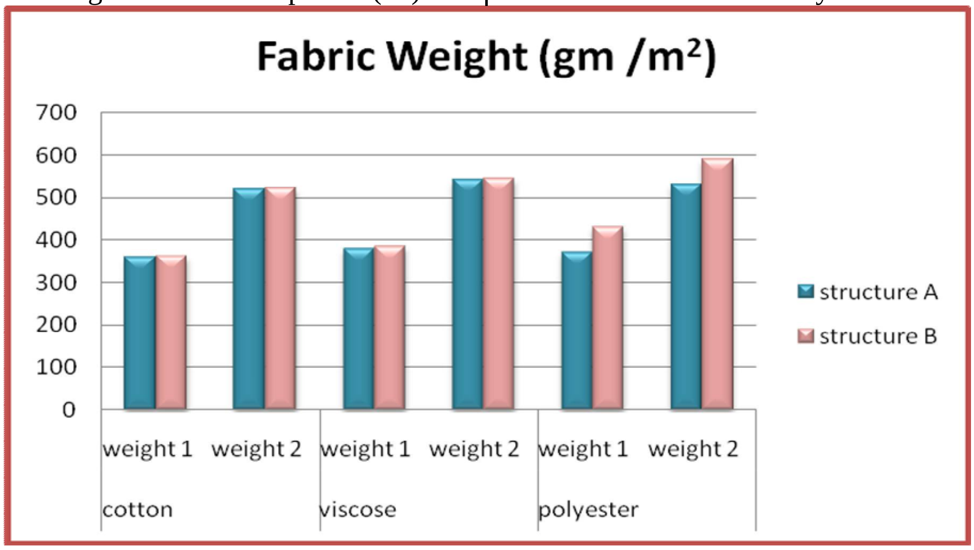

Figure (10) Effect of different weight of nonwoven fiber pad on multi-layered fabric weight

3.1.2 Multi-layered Fabric Thickness (mm)

Table (5) and figure (11) show the results of thickness test for different materials and different structure in samples.

Table (5) Results of multi-layered fabric thickness Test (mm)

structure	cotton		viscose		polyester	
	weight 1	weight 2	weight 1	weight 2	weight 1	weight 2
structure A	4.57	8.24	4.5	7.87	5.56	9.11
structure B	3.86	7.74	4.23	7.84	3.61	8.91

The thickness results are given in Table (5) and figure (11). It can be observed that the large thickness affected when used two layer of polyester wadded fiber with 320gm/m^2 to produce the multi layered fabric. Sample no(10) 320gm/m^2 of polyester wadded non-woven fabric and cotton/polyester top layer fabric in satin structure has the highest thickness .Sample no(11) 160gm/m^2 of polyester wadded non-woven fabric and cotton/polyester top layer fabric in Honey comb structure has the lowest thickness.

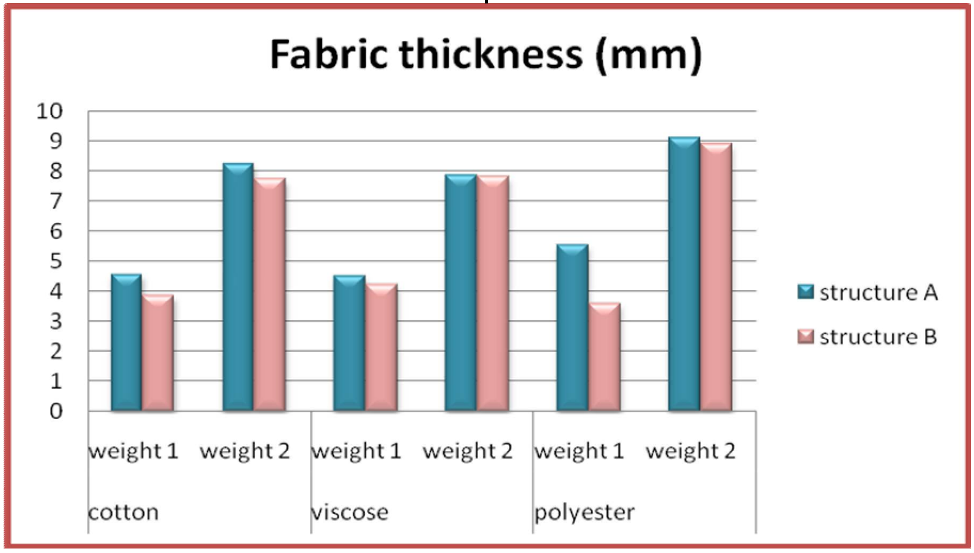

Figure (11) Effect of different weight in the ratio of nonwoven fiber pad on fabric thickness

3.1.3 Thermal transmittance for Multi-layered fabric (Tog)

Table (6) and figure (12) show the results of thermal transmittance for different materials and different structure in produced samples under test.

Table (6) Results of multi-layered fabric thermal transmittance Test (Tog)

structure	cotton		viscose		polyester	
	weight 1	weight 2	weight 1	weight 2	weight 1	weight 2
structure A	5.12	3.41	5.61	3.65	5.48	3.5
structure B	8.94	4.52	9.43	5.54	9.32	4.92

An important consideration is the amount of air space contained within a textile structure. Air has low thermal transmittance and high thermal resistance. Most textile fibers are poor conductors of heat, but air conducts even less heat. If air is confined in small spaces, then convection is also minimized, and the air is ‘dead’. The higher the volume of dead air within a textile structure, the lower the thermal transmittance, therefore, the better the insulation value of the textile material. [11]

In those spaces, there is little thermal transmittance because air is a very poor conductor of heat; and there is little radiation because although air is transparent to radiation, fibers are not. [11]

It is found from Table (6) that the thermal transmittance increases with the decrease in the number of fabric layer. The highest sample in thermal transmittance has been no (7) 9.43 Tog, with three fabric layers and two air gaps in between the fabric layers (top layer with Viscose weft yarns and Honey comb structure, middle with one layer of polyester wadded non-woven fabric and bottom) and the lowest sample was no (2) with four fabric layers and three air gaps in between the fabric layers (top layer with cotton weft yarns in satin structure , two layer in middle and bottom).Due to air is a very poor conductor of heat the sample with high thermal transmittance has low amount of air between layer and physical properties of the fibers such as the morphology and degree of polymerization of fibers, the less uniform cross sections of viscose fiber enable more thermal transmittance between fiber cross section shape than polyester and cotton.

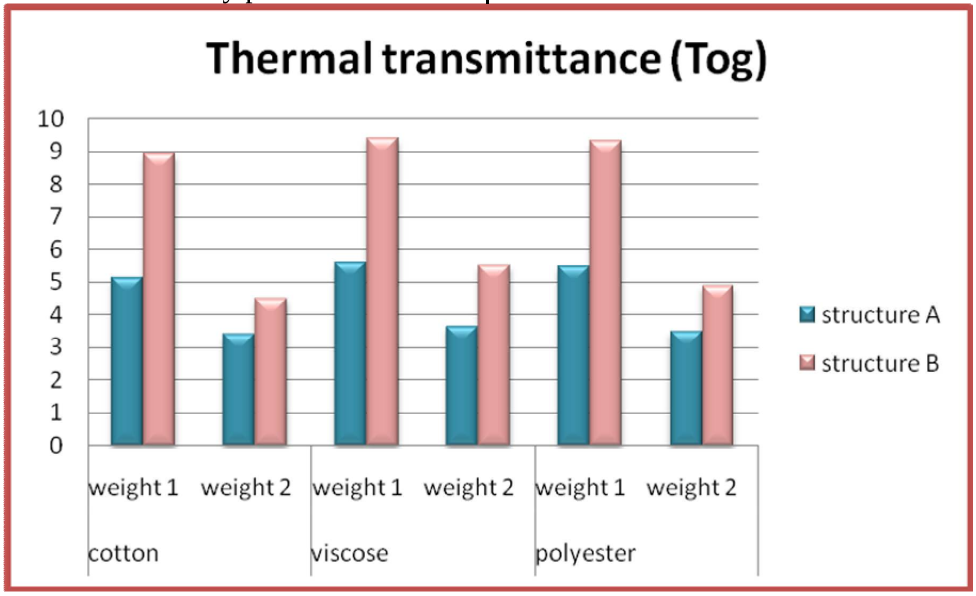

Figure (12) Effect of different weight in wadded nonwoven fiber pad on fabric thermal transmittance

3.1.4 Air permeability of multi-layered fabric

Table (7) and figure (13) show the results of Air permeability for different materials, different structure and different weight of fiber pad in produced samples under test.

Table (7) Results of multi-layered fabric Air permeability test (l/m^2/sec)

structure	cotton		viscose		polyester	
	Weight 1	weight 2	weight 1	weight 2	weight 1	weight 2
structure A	276	363	405	426	276	308
structure B	407	435	479	501	421	470

Table (8) Results of Air permeability test (fiber pad)

structure	weight 1	weight 2
structure B	6606	3962

Table (9) Results of Air permeability test, (multi-layered fabric without stitching the layer)

structure	weight 1	weight 2
structure B	415	447

Table (7) presents the results of the air permeability test. As the multi-layered fabric thickness increase, the air permeability increase. The air permeability of cotton/viscose top layer is higher than cotton/polyester and cotton 100% top layer, structure B(honey comb 8) is higher structure A(satin 5) , weight 2 (320gm/m^2) is higher than weight 1 (160gm/m^2).

Firstly in the normal case as shown in table (8) that weight 1 (160gm/m2) to the wadded fiber pad only is higher than weight 2(320gm/m2). Due to the increase in thickness reduce the air passes through the pores from the surface of the fiber pad.

Secondly the result presented in table (9) shown the air permeability of multi layered fabric without stitching the layer together, when increasing the weight 2 and the thickness trend with an increase in air permeability. On the other side weight 1 is lower weight and lower thicknesses shown reduce air permeability.

When we compared the results in table (7), (9) and figure (13) shown when made sandwich of multi-layer fabric with weight 2(fabric +2 layer fiber pad+ non-woven fabric) store a large amount of air between the layers leading to a higher rate of flow while the least weight and less thickness "weight 1"(fabric+ layer of fiber pad + non-woven fabric) as result to reduce the amount of store air between the layer , thus lead to less air permeability and Polyester fabric is seen lowest air permeability followed by cotton and viscose, depending on lesser number of pores of lower cross section area available for air passage.

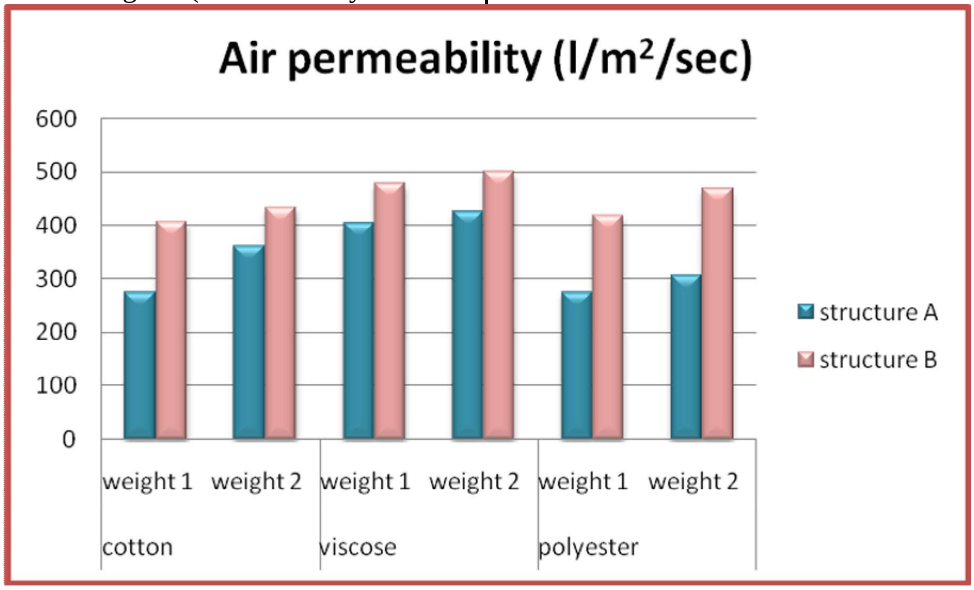

Figure (13) Effect of different weight in wadded nonwoven fiber pad on fabric Air permeability

Conclusions

From the previous results and discussion concerning some conclusions were achieved benefiting from it in the production of mattress multilayered fabrics and these could increase the functional performance of those fabrics. These conclusions are:

1. There is direct relationship between the ratio of the wadded nonwoven fiber pad inside the fabrics (weight 1 one layer and weight 2 double layer) and the weight test.
2. There is direct relationship between the number of layer inside the fabrics (weight 1 one layer and weight 2 double layer) and the thickness test.
3. The thermal transmittance increases with the decrease in the number of fabric layer and physical properties of the fibers such as the morphology and degree of polymerization of fibers, the less uniform cross sections of viscose fiber enable more thermal transmittance between fiber cross section shape than polyester and cotton.
4. There is direct relationship between the fabric thicknesses and air permeability.

References

1. Kandhavadivu Mallikarjunan, T. Ramachandran and B. Geetha Manohari " **Comfort and Thermo Physiological Characteristics of Multilayered Fabrics for Medical Textiles "** journal of textile and apparel,tecnologyand management ,Volume 7, Issue 1, Spring2011.
2. Nelles, **"Dress Up: Mattress Fabrics take on many roles"** , BedTimes Magazine, November 2009.
3. Nazare et al.," **Assessment of factors affecting fire performance of mattresses"** Fire Science Reviews 2012.
4. Dominick Alevedo**," Quilted Mattress Panels with Gel Fibers and Mattresses Made with Same"** Patent Application Publication, United States, Oct. 31, 2013.
5. R.A. Chapman **"Applications of Nonwovens in Technical Textiles"** Wood head Publishing ,2010.
6. Pezzin Albertossa **"Thermo Physiological Comfort Modeling of Fabrics and Garments"** POLITECNICO DI TORINO Department of Applied Science and

Technology PhD in Chemical Engineering, 2014.

7. ASTM-D-3776-79, **Standard test method for measuring fabric weight**
8. ASTM-D-1777-1996, **Standard test method for measuring thickness of textile materials**
9. “ASTM D: 1518-85(2003) **Standard Test Method for Thermal Transmittance of Textile Materials.”** 85-2003.
10. American Standard Specification of (ASTM-D737-04(2012) **Standard Test Method for Air Permeability of Textile** .
11. Md. Ibrahim and H. Mondal **"Textiles: History, Properties and Performance"** ISBN: 978-1-63117-262-5 Nova Science Publishers, 2014.