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Performance of Needle-Punching Lining Nonwoven Fabrics and their Thermal Insulation Properties

Sanaa S. Saleh

Associate Professor, College of Girls for Science, Arts and Education, Ain Shams University, Cairo, Egypt

ABSTRACT

Using the needle punching technique, nonwoven needle punched fabrics have been produced. 5 needle punched fabrics, made for quilts and garment interlinings have been produced using needle punching machine. 3 nonwoven fabrics are produced as quilt interlinings and 2 are produced as garment interlinings. The fabrics are produced using different weight per unit area and fiber type. Virgin polyester 100% fibers, polyester and cotton virgin fibers and polyester and recycled fibers are used for the quilt fabrics. For the garment interlining, 100% polyester virgin fibers are used, and one fabric is compressed while the other fabric is not. The air permeability properties and the thermal insulation properties are investigated. Mechanical properties have also been investigated such as strength and elongation. Also, some other physical properties such as compression properties under different loads are also examined.

Keywords: Nonwoven lining fabrics, needle-punching technique, recycled fibers, compression and air permeability properties, thermal insulation properties.

1- INTRODUCTION

1-1 Nonwovens quilts and garment interlinings

Nonwovens are new players in the world of fashion design. Traditionally involved in the apparel industry for interlinings, clothing accessories, insulation and shoe components, etc [1].

The generic term “nonwoven interlinings” defines materials based on nonwovens that are incorporated into articles of clothing during production to fulfill a range of functions [2].

Interlining nonwoven fabric is a layer of fabric inserted between the face and the lining of a garment, drapery, or quilt. Interlining is similar to batting, a thick layer of fiber designed to provide insulation, loft, and body to quilts, pillow toppers, and heavy winter jackets. Depending on the application, interlining materials can be woven, knitted, or created by fusing fibers together. Silk, wool, and artificial fibers with good insulating qualities are common choices for interlining [3].

The processing methods used can be divided into sewn and bonded interlinings (fusible interlinings). Sewn interlinings are incorporated between the shell and the lining material during the sewing process. Bonded interlinings are fused to the shell, lining or another inlay material by a bonding process (heat sealing process). The ratio of sewn to bonded interlinings is currently approximately 20:80 [2].

Most of the interlinings are made of nonwoven fabrics. There are various definitions of a nonwoven fabric. For example, according to Textile Terms and Definitions, nonwoven fabrics can be defined as textile structures made directly from fiber rather than yarn [4].

According to other definitions, Interlining is an insulation, padding, or stiffening fabric, either sewn to the wrong side of the lining or the inner side of the outer shell fabric. The interlining is used primarily to provide warmth in coats, jackets, and outerwear. Also, Quilting is defined as a fabric construction in which a layer of down or fiberfill is placed between two layers of fabric, and then held in place by stitching or sealing in a regular, consistent, all-over pattern on the goods [5].

The domestic market for nonwoven fabrics used for internal construction applications in upholstered furniture and bedding is a large; Nonwovens are primarily used as internal construction fabrics in the arms/backs, as spring insulators, dust covers, pull strips, cushion/pillow tickings.

Interlinings are one of the end uses that have historically had small growth in the nonwovens industry in all over the world [1].

***Corresponding Author:** Sanaa S.Saleh: Associate Professor, College of Girls for Science, Arts and Education, Ain Shams University, Cairo, Egypt

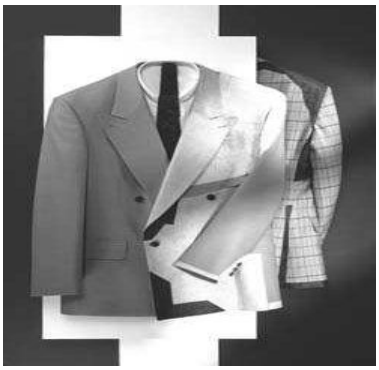

Figure 1: Nonwoven interlinings for providing bulk and heat insulation [2]

1-1-1 Functions of nonwoven quilt & garment interlinings

Every nonwoven interlining has a range of functions to fulfill, related to its end-use, that should satisfy both the processor (garment manufacturer) and the purchaser of the garment (consumer). Due to the complexity of the factors affecting the production and use of garments, a universal nonwoven interlining is inconceivable. This means that it is necessary for the manufacturer to establish the required properties of the made-up article by close communication with the shell manufacturers and garment manufacturers and by monitoring the consumer market, and from this to determine the specification of the nonwoven interlining.

By using the resulting specification, a suitable nonwoven interlining can be developed and constructed for almost any end-use. In general, the functions of a nonwoven interlining can be divided into three main groups [2]:

Interlining fabric for shaping and support

Shaping and support are the traditional tasks of an interlining fabric. It forms the internal frame of garments (for example jackets and coats) and helps to absorb and bear the static and dynamic stresses to which the garment is subjected in use. The shape given to the clothing for anatomical or fashion reasons should be maintained permanently by the interlining without changing the textile properties of the shell. A nonwoven interlining of this type is primarily used over a large area (front fusing interlining).

Nonwoven interlining for stabilizing and/or stiffening

The task of a nonwoven interlining used for stabilizing is to reinforce or stiffen certain parts of a garment in the desired way. Moreover, these areas, often the most visible on a garment (for example collars and cuffs on shirts and blouses), should look good and should not lose their appearance after the care cycle. In terms of their application, these nonwoven interlinings are primarily for use over small areas and aid rationalization as punched and narrow fabrics

Nonwoven interlinings for providing bulk in applications such as quilts

So-called quilting nonwovens can fulfill two different tasks in garments. The first, as a backing for quilting or embroidery to create a decorative look is determined by fashion. These are normally used over a small area.

The second task of providing heat insulation conforms to the rules of clothing physiology. With an entrapment of air of over 90%, these nonwovens make ideal heat insulators and stand out from other textile fabrics in this respect. In this case, the filling material is used over a large or the whole area. The boundaries between the two tasks can be fluid [2].

1-1-2 Properties of nonwoven interlinings

The property characteristics of a nonwoven interlining ensure that it fulfils the required function. Here, it should be noted that

– For one function several properties can sometimes be decisive
– Individual properties have effects on various functions
– Not all possible properties are relevant for every nonwoven interlining.

1-1-3 Functional elements of nonwoven interlinings

By using the basic elements of a nonwoven interlining, that is the raw materials (fibres, binders, finishes, hot melt adhesives), by combining them together and using the different manufacturing possibilities, such as web formation, finishing, application and formulation of the hot melt adhesive, it is possible to design the individual properties and therefore to fulfill any function. These basic elements are therefore functional elements for the nonwoven interlining. The relationship between the functional elements and the properties can be represented in a matrix. ***The aim of such a matrix is:***

– To supply data on which functional elements are relevant for a property
– To provide the basis for specifications for stages carried out by external manufacturers
– To provide the stimulus for new or improved technical equipment [2]

1-2 Needle punching process:

Most of interlinings used for garments & quilts are produced from needlepunching process which is a process that is also known as needle felting. It is developed to produce mechanically bonded nonwoven fabrics from fibres that could not be felted like wool of a simple needleloom. The fibres are mechanically entangled to produce a fabric by reciprocating barbed needles (felting needles) through a moving batt of fibres in a needleloom. The barbed needles are clamped into a board which oscillates vertically between two fixed plates containing the moving batt, each plate being drilled with corresponding holes through which the needles move. A feed system introduces the batt between the lower bed plate and the upper stripper plate by nip rollers or aprons, whilst a nip roller system draws the consolidated web away from the needling zone. As the web moves through the loom, more fibres are progressively entangled by the needle barbs and a coherent fabric structure is formed.

Originally, the products of needling were made from fibres such as jute, coir, hair, waste and shredded rags to produce carpet underlay, mattress padding, insulation and rough blankets, the manufacture being relatively crude and dusty [6, 7]

Mechanical bonding of fibrous web has started with coarse fibres and after multiple modifications was made applicable to waste and manmade fibers. The share of needle felting and other nonwoven technologies, namely thermal and chemical bonding, has become very popular [8, 9].

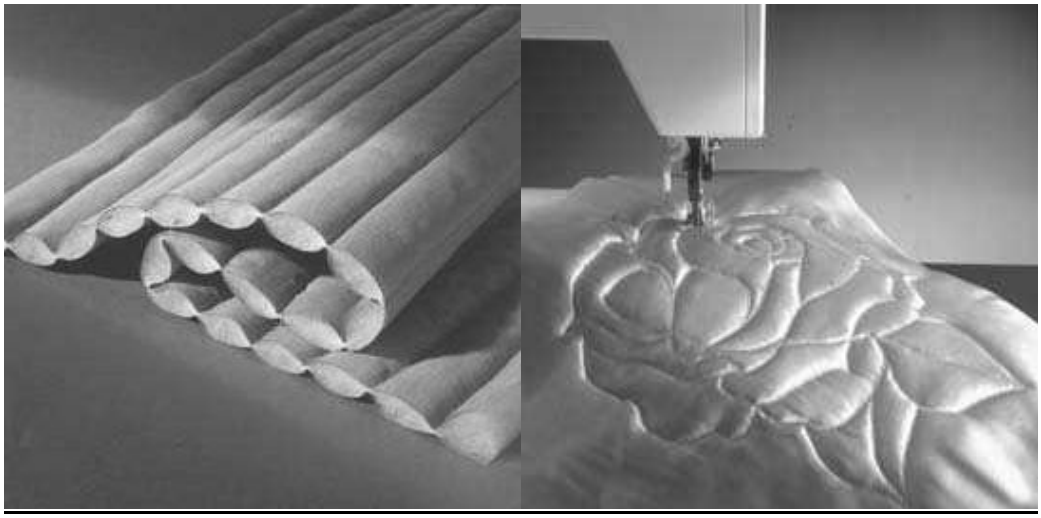

Figure 2: Nonwoven interlinings for providing bulk and heat insulation (quilts) [2]

2- Experimental Work

<u>2-1 Method of Production and fabric specifications:</u>

The needle punching technique has been used in the production of the 5 lining fabrics. 3 fabrics are produced for the quilt linings and 2 for the garment interlinings. The weight per unit area for the quilts ranges from approximately 320 – 440 g/m^2. Whereas, the weight per unit area for the garment interlinings ranges from approximately 80 – 108 g/m^2. It should be noticed that the first garment interlining has a fluffy structure (fabric 4), whereas the second one (fabric 5) has been compressed during production

Table 1: Specification of quilts & Garment lining fabrics

Sample No.	Fibre composition	Fibre type	Weight	Application	Production method
1	100% polyester	Virgin fibres	322.1 g/m^2	Quilts	Needlepunching
2	15% polyester virgin fibres, 85% polyester recycled fibers & blends	Blended virgin and recycled fibres	441.2 g/m^2	Quilts	Needlepunching
3	50%, 50% cotton, polyester virgin fibres	Blended virgin fibres)	378.4 g/m^2	Quilts	Needlepunching
4	100% polyester fibres (fluffy)	Virgin fibres	79.5 g/m^2	Garment interlinings	Needlepunching
5	100% polyester fibres (compressed)	Virgin fibres	107.4 g/m^2	Garment interlinings	Needlepunching (compressed)

2-2 Photos taken by the optical microscope of quilt lining fabrics:

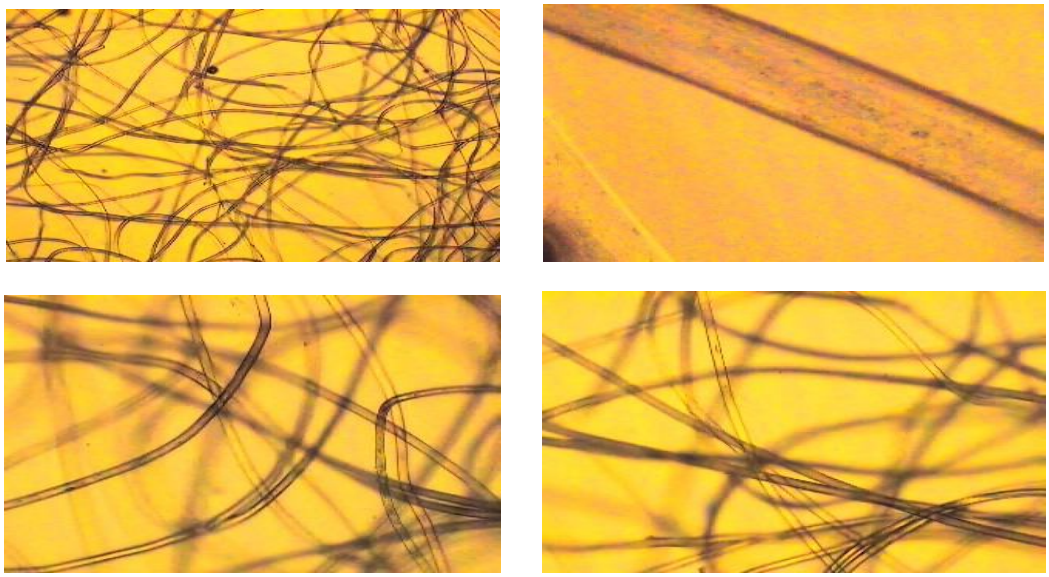

Figure 3: Set of pictures for fabric 1

Figure 3 show some pictures taken by the optical microscope for Fabric 1 which is produced from 100% polyester virgin fibers. It can be seen the homogenous of the fibers used in this fabric.

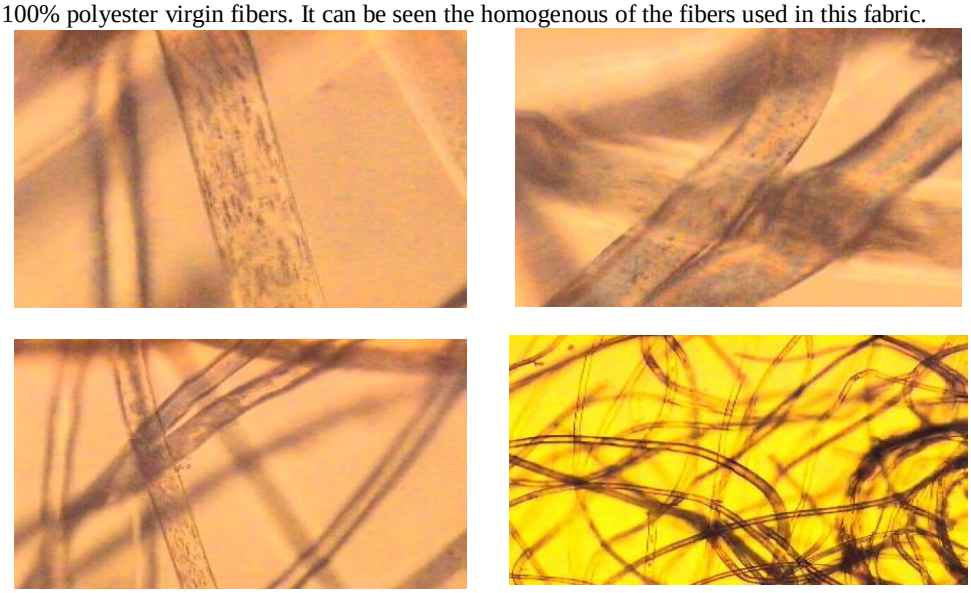

Figure 4: Set of pictures for fabric 2

Figure 4 show pictures taken by the optical microscope of fabric 2. Fabric 2 obtained more than one type of fibers as its components are 15% virgin polyester fibers and 85% of polyester recycled fibers & blends. It can be seen the difference in fiber diameter and shape.

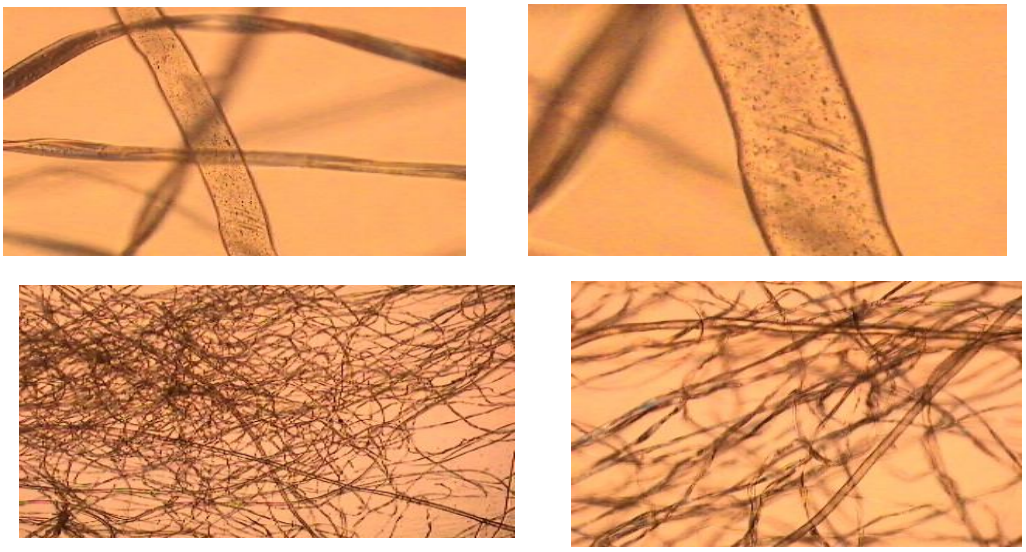

Figure 5: Set of pictures for fabric 3

Figure 5 represents pictures of fabric 3 which are taken by the optical microscope. Fabric 3 obtained two types of fibers; cotton and polyester fibers which have different shape and structures.

3- ANALYSIS & DISCUSSION

3-1 Compression properties

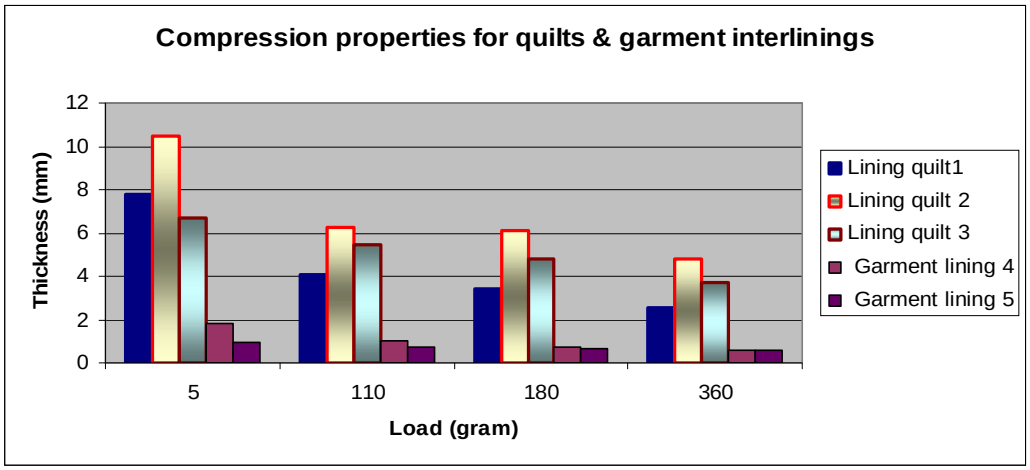

Figure 6: Relationship between loads applied in grams and fabric thickness in m m (Compression Properties)

In figure 6 represents the thickness values of the quilt lining fabrics 1, 2 and 3 under different loads; 5, 110, 180 and 360 grams respectively. For fabric 1, the thickness decreased by 42.3% after increasing the load from 5 to 110 grams. Then the thickness decreased by 14.8% after increasing the load from 110 to180 grams. Followed by a decrease of 26.4% after increasing the load from 180 up to 360 grams.

For fabric 2, it is found the thickness decreased by 43.17% after increasing the load from 5 to 110 grams. Then the thickness decreased by 2.25 % after increasing the load from 110 to180 grams. Followed by a decrease of 21.05% after increasing the load from 180 up to 360 grams.

For fabric 3, it is found the thickness decreased by 18.39% after increasing the load from 5 to 110 grams. Then the thickness decreased by 12.45 % after increasing the load from 110 to180 grams. Followed by a decrease of 22.38% after increasing the load from 180 up to 360 grams.

It can be noticed that quilt lining fabric 1 (100% polyester) and fabric 2 (polyester and recycled fibers) compressed by relatively higher amount after increasing the load from 5 to 110 grams compared with fabric 3 (blended polyester/cotton fibers) after using same amount of loads. Followed by relatively lower amount of compression under the loads (180 and 360 grams) in case of fabrics 1 and 2. But for fabric 3, the compression that took place was gradually taking place after applying the same loads starting from 110 up to 360.

In case of quilt lining fabric 2, the highest amount of weight per unit area and fabric thickness could be the main reason for high amount of relative compressibility after applying the first load compared with other fabrics.

But for quilt lining fabric 1, using virgin polyester fibers (100%) may be the reason of high compressibility obtained for this fabric after applying the first load. So that the fabric weight per unit area and type of fibers used are the main reasons that affect the fabric compressibility of quilt interlinings in this research.

Also, in figure 6, it can be seen that for garment lining fabrics 4 and 5; the results are different compared with these of the quilt fabrics. Generally the ratios of decrease for these fabrics are much lower for the previously quilt fabrics (1, 2 and 3 in figure 6). For fabric 4, the thickness decreased by 50% after increasing the load from 5 to 110 grams. Followed by a decrease of 26.2% after increasing the load from 110 to 180 grams. And followed by another decrease of 19.17% after increasing the load from 180 to 360 grams.

But for fabric 5, the situation is different, where the decrease of thickness is relatively lower **compared with fabric 4**. For example, the thickness decreased by 19.7% after increasing the load from 5 to 110 grams. Followed by a decrease of 5.5% after increasing the load from 110 to 180 grams. And followed by another decrease of 8.7% after increasing the load from 180 to 360 grams. These results are generally lower compared with fabric 4 and can be a result of that fabric 5 is a compressed fabric (see table 1).

Comparing the results obtained for quilts and garment interlinings, it can be noticed that the compression properties for garment interlinings are generally lower compared with that of the quilt interlinings. And this can be as the quilts are generally having higher thickness compared with the garment interlinings so that they have higher opportunity to compress under certain loads.

3-2 Elongation Properties

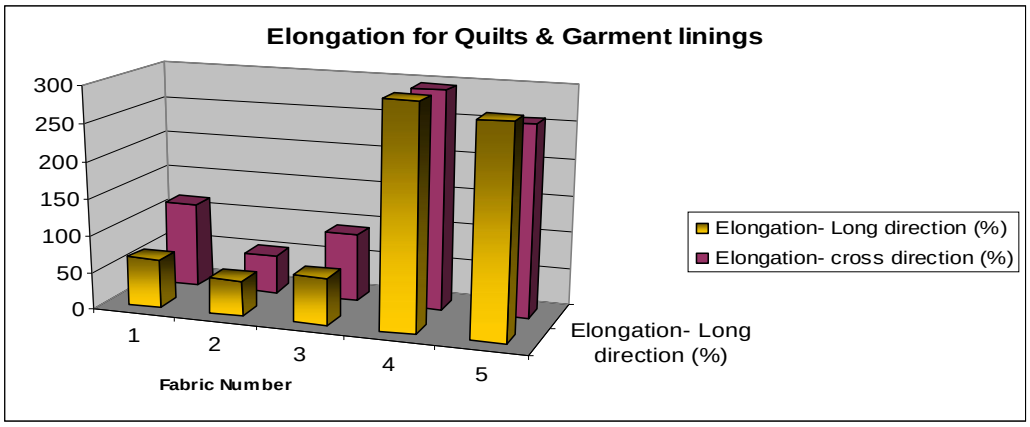

Figure 7: Fabric numbers Vs Elongation in %

Figure 7 represents the elongation values obtained for quilt lining fabrics 1, 2 and 3 and also of the garment lining fabrics. It's clear that the elongation is generally higher in the cross direction for all the fabrics and this is due to the general inherent structure of the non-woven fabrics. Also, it can be seen that the higher values obtained for elongation in both long and cross direction were for fabric 1. This can be as a result of lower thickness and weight per unit area. In contrast to this, fabric 2, as it has the highest weight per unit area and fabric thickness and hence has the lowest amount of relative elongation.

On the other hand, for the garment interlinings, generally, the elongation of fabric 5 (the compressed structure) is lower than that of fabric 4 in both directions. It also can be seen that the elongation for fabric 4 is higher than that for fabric 5. This can be explained as a result of the compressed structure of fabric 5 which obstruct the fabric elongation.

Generally, the elongation of the garment lining fabrics is higher than that of the quilt lining fabrics due to lower weight per unit area & thickness properties.

3-3 Strength Properties:

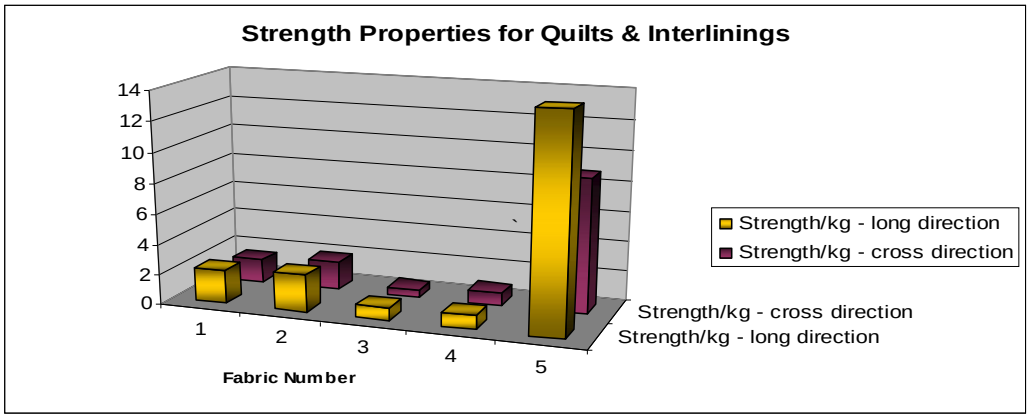

Figure 8: Fabric numbers Vs fabric strength in kg

In figure 8, it can be seen that generally the strength values obtained for the fabrics are higher in the long direction compared with that in the cross direction and this is due to the general inherent structure of the non-woven fabrics. It also can be seen that the higher strength values, **for the quilt fabrics,** are obtained for fabrics 2. This can be explained as a result of the highest weight per unit area and thickness compared with the other two fabrics (1 and 3). On the other hand, the strength values obtained for fabric 1 is higher than that of fabric 3 although fabric 3 has a higher thickness and weight per unit area than fabric 1 (see table 1). This can explained as a result of fiber type used in both of them, where fabric 1 is made of 100% polyester virgin fibers and fabric 3 is made of 50, 50% cotton, polyester fibers, and as known, the polyester fibers have higher strength than cotton or cotton blend fibers.

Also, in figure 8, the results obtained for both strength values for **garment lining** fabrics 4 and 5 in both the long and cross directions. The two fabrics are made of 100% polyester virgin fibers and produced under similar conditions. Similarly, the strength values in the long directions are higher than that in the cross direction as mentioned and explained earlier. Fabric 5, obtained the highest values of strength compared with fabric 4 according to relatively higher weight per unit area (see table 1) and also as a result of the fabric being compressed during the manufacturing process, which provide more strength to the fabric.

3-4 Relationship between both thickness & weight per unit area and air permeability

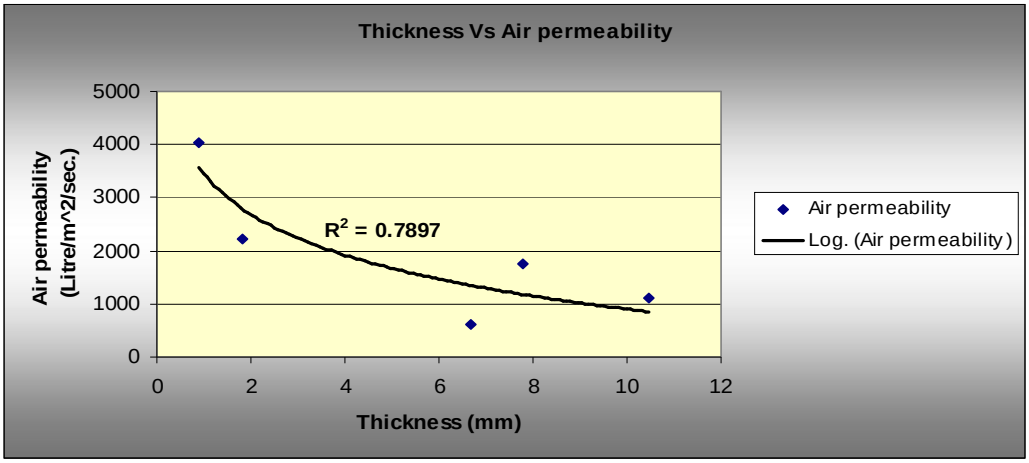

Figure 9: Thickness Vs Air permeability

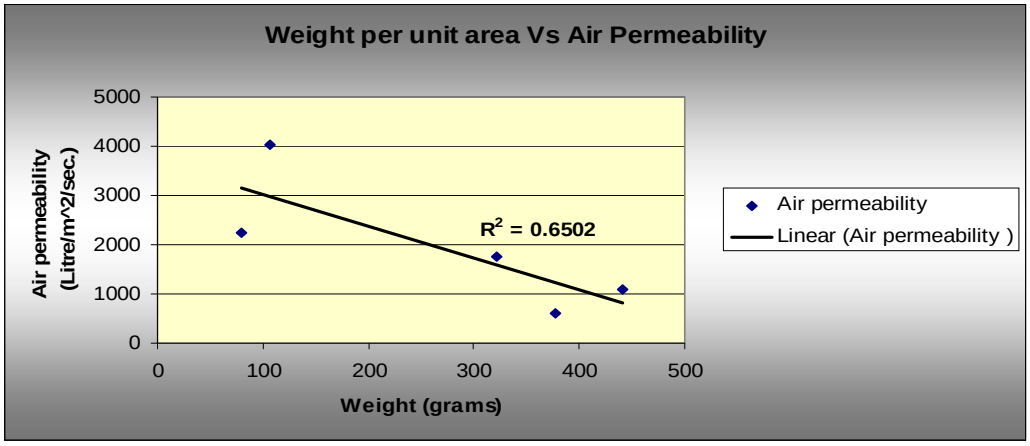

Figure 10: Weight per unit area Vs Air permeability

Figures 9 and 10 represent the relationships between both thickness & weight per unit area and air permeability properties. It is clear that increasing both thickness and weight of the lining fabrics result in decreasing the air permeability of these fabrics.

3-5 Relationship between both thickness & weight per unit area and thermal insulation properties

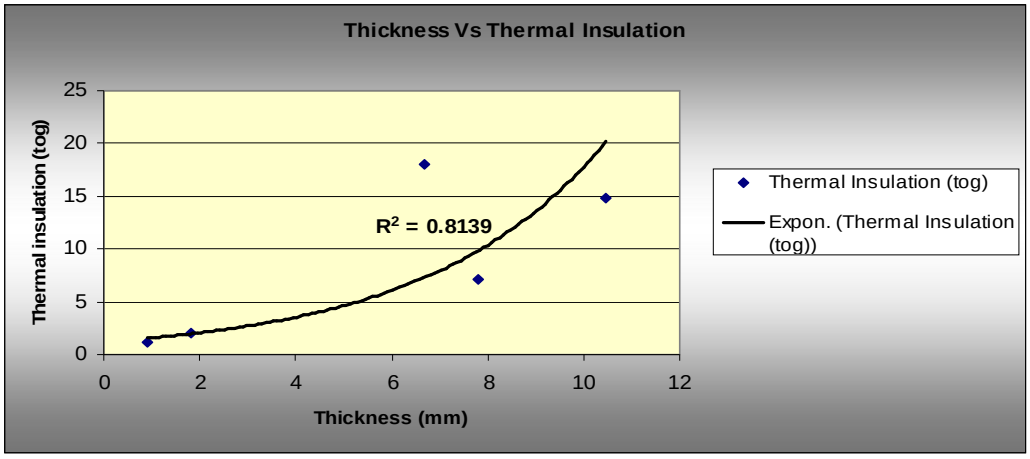

Figure 11: Thickness Vs Thermal insulation

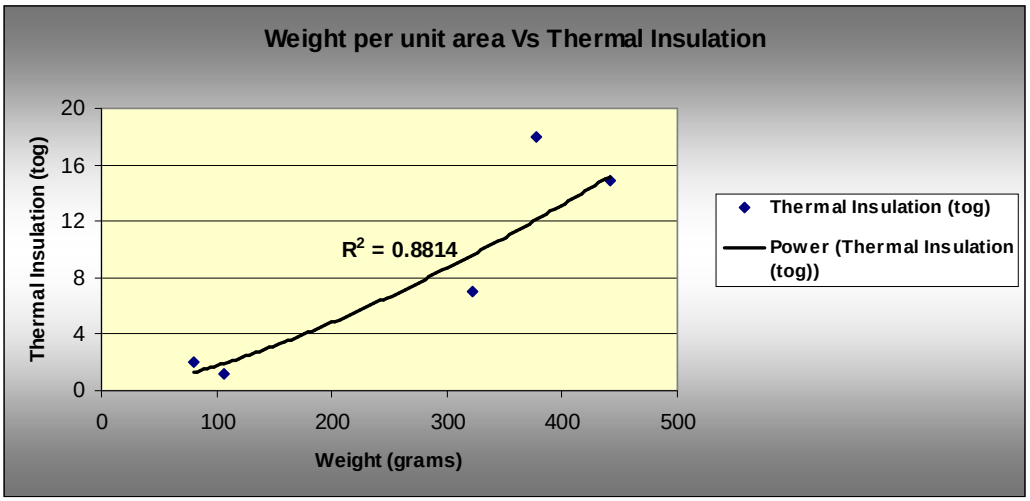

Figure 12: Weight per unit area Vs Thermal insulation

Figures 11 and 12 represent the relationships between both thickness & weight per unit area and thermal insulation properties. On the contrary, it is found that increasing both thickness and weight of the lining fabrics result in increasing the thermal insulation of these fabrics.

3-6 Relationship between fabric structure and air permeability

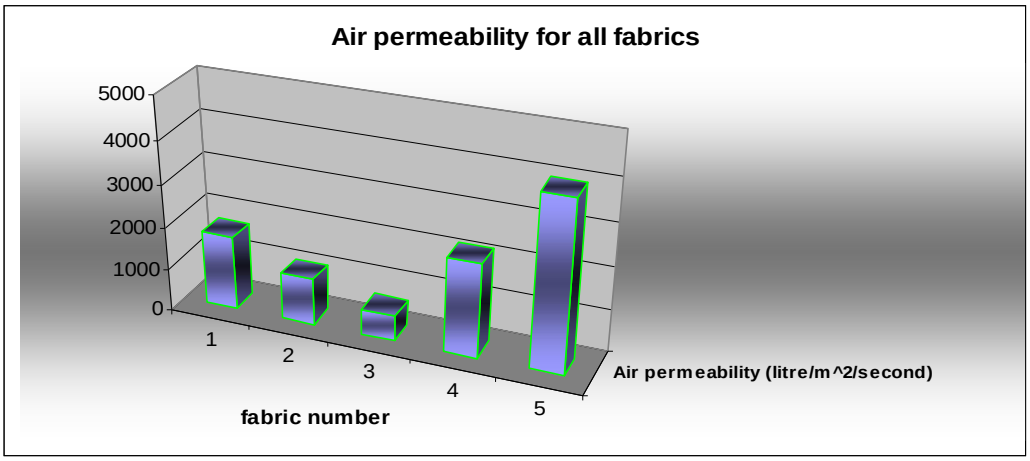

Figure 13: Fabric numbers Vs fabric air permeability in (litre/m^2/second)

Figure 13 represents the air permeability values obtained for all the fabrics. It can be seen the fabrics 4 and 5 have the highest values of air permeability compared with all the quilt fabrics. This can be explained as a result of lower thickness and weight per unit area obtained for these two fabrics. And as shown previously in figures 9 and 10, there are relationships between both thickness & weight per unit areas and the air permeability properties.

On the other hand, fabric 1 has the highest value of air permeability, compared with the other quilt lining fabrics (fabrics 2 and 3) according to its lower thickness value compared with fabrics 2 and 3 (see figure 6 and 9). Fabric 2 has higher air permeability compared with fabric 3, although it has a higher fabric thickness than fabrics 3, this can be as a result of using recycled fibers in its production whereas fabric 3 is made from virgin blended fibers. This can be explained as the recycled fibers allow more air to pass through them as a result of their compressed condition from previous processing and weakness status that do not allow them to obstruct the flow of air passed within the fibers of the fabric.

Also, it can be noticed that, fabric 5 which has a compressed structure and lower fabric thickness according to that compression, is having higher air permeability compared with fabric 4.

Accordingly, it can be concluded that the more recycled fibers used, the more air permeability allowed.

3-7 Relationship between fabric structure and thermal insulation properties:

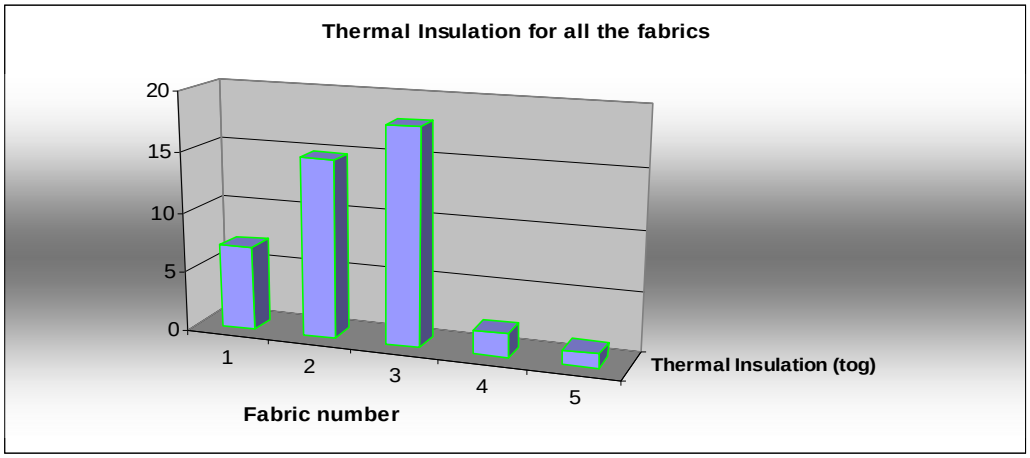

Figure 14: Fabric numbers Vs thermal insulation

Figure 14, represents the values of thermal insulation obtained for all the fabrics (1-5) in tog values. Fabric 2 has the highest thickness followed by fabric 3 and then fabric 1. Although that, fabric 2 has the highest thickness values, but the thermal insulation properties for fabric 3 are higher than that of fabric 1 and 2. These results may be explained as a result of fabric weight per unit area and thickness in the first place (see figures 11 and 12). The fiber type may be the second reason that affects the insulation properties. This may be explained as the previously manufactured or processed fibers (recycled fibers) have more ability to compress, and hence lower amount of air around the fibers are available, which lead to less amount of thermal insulation within the fabric produced. This conclusion can be more obvious when applied on fabric 2 which is produced from recycled fibers (85%), as although it has the highest weight per unit area and thickness, but fabric 3 (blended virgin fibers) has a higher amount of thermal insulation compared with it.

Generally, it can be noticed that fabrics 4 and 5 have lower fabric thermal insulation values compared with the rest of the fabrics due to lower fabric thickness. Also, it can be noticed that the thermal insulation for fabric 4 is higher than that of fabric 5 although the weight per unit area for fabric 5 is higher than that of fabric 4. This can be explained as a result of that fabric 4 has a fluffy structure which allow more trapped air that can provide more thermal insulation compared with fabric 5 which has a more compressed structure that can reduce the amount of trapped air within and between the fibers and hence reduce the amount of fabric insulation.

These results show the inter-relationship between both thickness & weight per unit area and type of fibers used and their effects on thermal insulation properties obtained of the quilt linings and garment interlinings as well.

3-8 Relationship between air permeability and thermal insulation properties for the quilt & garment lining fabrics:

From figures 13 and 14, it can be concluded that there is an inversely relationship between the air permeability and thermal insulation that can be obtained and this can be investigated and shown in figure 15.

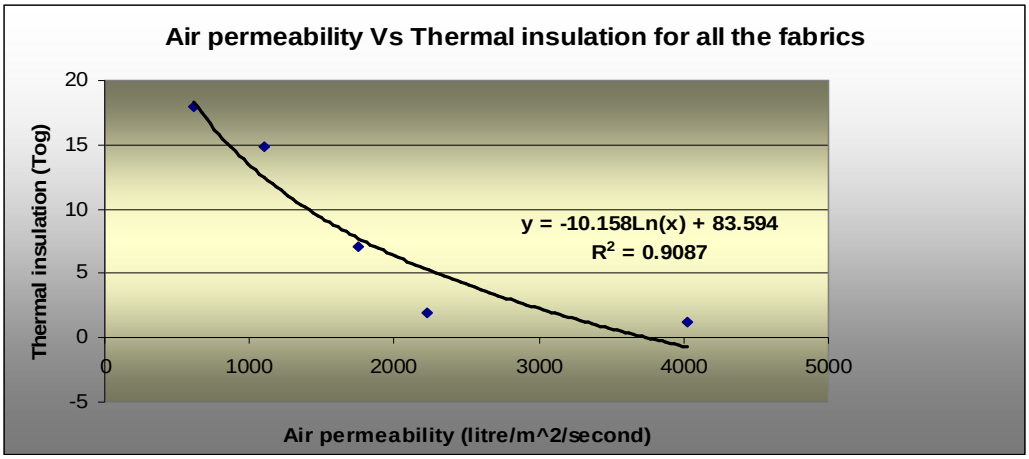

Figure 15: Relationship between air permeability and thermal insulation

Figure 15 represents the relationship between the thermal insulation and the air permeability for lining fabrics 1-5 respectively and R square is also obtained. It can be seen that there is certainly a strong inversely relationship between air permeability and thermal insulation. This can be explained as the more porous and air permeable the fabric is, the less trapped air obtained which gradually decrease the amount of thermal insulation that can be developed.

As where fabrics 4 and 5 have high air permeability, in figure 13, it can be noticed that they have the lowest thermal insulation obtained in figure 15 due to their higher air permeability properties.

4- Conclusions:

1- For the quilts & garment lining fabrics, the compression properties depend to great extent on the weight per unit area, thickness and fiber type that has been used. Also, it depends on their type of production (compressed or not). It has been found that the non-compressed fabrics allow more compression when applying loads on the fabrics compared with the compressed ones.

2- For the quilt and garment nonwoven interlinings, it is the fabric weight per unit area, fabric thickness, fiber type and also the structure of the fabric that affect the strength and elongation of the nonwoven fabrics used in this paper. The higher the fabric weight and thickness, the higher the fabric strength is and the lower the elongation. The compressed nonwoven interlining fabrics gave higher fabric strength and lower fabric elongation compared with the non-compressed ones.

Also, and as usual the strength in the long direction is higher than that in the cross direction as a result of the inherent structure of the nonwoven fabric.

3- Concerning air permeability properties of quilt and garment nonwoven lining fabrics, it has been found that either fabric thickness, weight per unit area and fiber type are responsible for the air permeability properties obtained in this paper. It is found that the lower thickness and compressed nonwoven interlining fabric has higher air permeability compared with the non-compressed with higher thickness value interlining fabrics.

4-Concerning thermal properties of quilt and garment nonwoven lining fabrics in this paper, it is found that fabric thickness, weight per unit area and fiber type affect the thermal properties of the fabrics. The results show the inter-relationship between both thickness and type of fibers used and their effects on thermal insulation of the quilt and garment lining fabrics. The compressed nonwoven linings show lower thermal insulation properties compared with the non-compressed nonwoven linings due to the possible amount of trapped air in case of fluffy non-compressed lining that provide more thermal insulation.

5- It is concluded that the more recycled fibers used, the more air permeability allowed, and hence less thermal insulation can be provided.

6- The results show that there is an inter-relationship between thickness and type of fibers used and both air permeability and thermal insulation properties of the quilt & garment linings.

7- There is an inversely relationship between thermal insulation properties and air permeability properties for all the quilt and garment interlining nonwoven fabrics examined in this paper.

8- Finally, it is recommended to use virgin fibers in the production of quilts and garment interlining and other applications that need high amount of thermal insulation. Whereas, in other industrial applications, where thermal insulation is not concerned, the recycled fibers can be used.

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5- REFERENCES

1- www.highbeam.com

2- Assent, H.Cl, 2003, Nonwoven Fabrics, raw material, Manufacture, Applications, Characteristics, Testing Processes", ISBN 3-527-30406-1.

3- www.wisegeek.com/what-is-an-interlining.htm

4- McIntyre, J E and Daniels PN, (1995):Textile Terms and Definitions, Tenth Edition, The textile Institute

5- www.fabric.com/SitePages/Glossary.aspx

6- Anand, S C, Brunnschweiler, D, and Russell, S J., 2007, "Handbook of Nonwovens", the textile institute, Woodhead Publishing ISBN-10: 1-84569-199-7 (e-book)

7- Smith, P.A., 2000, "Technical fabric structures- Nonwoven fabrics, needlefelting", "Handbook of technical textiles", the textile institute. CRC ISBN 0-8493-1047-4.

8- Vijay P. Gupta, "The application of Needle Felting technology for technical textiles and home furnishing", Papers of National Conference on Nonwovens, the textile Institute, North India Section, 1992

9- Krcma, R., “Manual of Nonwovens”, 1971, the Textile Trade Press

10- ASTM D 6222:2002

11- ASTM D 737-75:1980

12- Egyptian Standard Testing Method: 680:2002

13- Egyptian Standard Testing Method:4-295:2008

14- Egyptian Standard Testing Method: 122:2008

15- Egyptian Standard Testing Method: 3063:1996

16- Egyptian Standard Testing Method: 122:2008