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DESIGNING AND PRODUCING NON-WOVEN FABRICS USED AS INSULATOR LAYERS IN INNERSPRING MATTRESSES

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ABSTRACT

Mattress is a large pad for supporting the reclining body, used as a bed or a part of a bed and are generally consisted of two different layers, the comfort layer and the support layer, the comfort layer comprises of materials such as polyurethane foam, polyester fabric and natural fibers. The support layer or innerspring unit is created with a series of coils and springs. This support layer acts as the core of the mattress. This research aims to produce non-woven fabrics suitable for using as insulator layer in innerspring mattress whereas the insulator pad is put directly on top of the coils to keep the spring from pushing through the padding material or to insulate the upholstery from the core and to absorb the resulted stresses from the motion of the innerspring.
Non-woven technique was used to produce 9 samples. Two types of textile materials were used, polyester, waste and reinforced waste. Polyester fabrics is produced using two types of fibers count (9 den., 15 den.) ,two types of fibers melting at (100 ^{o}C, 130 ^{o}C) then the polyester fabrics pass between two hot calendars at 120 ^{o}C, waste fabrics pass between two hot calendars at 100 ^{o}C. Reinforced waste is produced using woven polypropylene ribbons. Tests are carried out to evaluate the samples produced under study. The obtained test results are presented and discussed.

Keywords: Hometech textile, Innerspring core, Insulator layer, Mattress, Upholster layer (cushioning).

I. INTRODUCTION

Hometech Textile has attracted considerable attention more than fabrics, nonwoven and composite reinforcements, and lies in the field of furniture, house hold textiles and furnishing. This sector has got its significance in today's corporate world due to the consumer's change in life style.[1] Process complexities, requirement of specific products, demand for comfort, security situation and well furnished and modern home, Hometech industry is considered as one of the emerging areas with huge potential in the technical textile field all over The world.
Hometech is that part of technical textile which converts house into home. All fabrics which are used in the home come under the Hometech. Home textile industry has become sparkling place in the textile Industry. [2] Soft bedding products are main upholstered furniture in a bed room. Usually, upholstered furniture are

cushioned with batting or foam and covered in fabric or leather, they are also widely adopted at other home or commercial such as sofas, restaurant seating, dining room chairs, car seat, etc. In a bedroom, it mainly includes mattress and soft beds with different styles of designs that suit various personal tastes. By nature of upholstered furniture, soft coverings of beds and mattress increase the comfort level of utilizer when comparing to a hard, wooden bed. With the progressing development of technology and living standard of people, manufacturers of mattress and soft beds have researched into abroad range of design and production techniques in order to meet the desired comfort, harmony atmosphere, relax and luxury feelings of utilizer.[3]

1.1. A Mattress:

A mattress is a large pad for supporting the reclining body, used as a bed or as part of a bed. Mattresses may consist of a quilted or similarly fastened case, usually of heavy cloth, that contains hair, straw, cotton, foam rubber, etc, or a framework of metal springs. Mattresses may also be filled with air or water.

Mattresses are generally consisted of two different layers, the comfort layer and the support layer. The comfort layer comprises of materials such as polyurethane foam, polyester fabric, and natural fibers. The support layer or innerspring unit as its called is created with a series of coils and springs. This support layer acts as the core of the mattress.[4]

Developing mattresses which reduce pressure point on the human body will correlate with sleeping quality. So the better mattresses are required to decrease the load on the waist and the back. Specifically, the provision of the mattress that can maintain natural body posture and rollover ease. The conventional flexible polyurethane foams used in mattresses have been made using a dual layer or profile cut surface to improve human body pressure distribution.[5]

Mattresses support the human body through the development of a mechanical equilibrium between a body of given to total weight and mattress whose resistance to deformation increases with the depth of penetration by the supported body. Although the weight of the body deforming a mattress or overlay is contrast, the applied pressure at the body/ mattress interface changes with increasing area of contact for this reason minimum average pressure is achieved with maximum envelopment of the body by the mattress.[6]

1.2. Types of Mattresses:

1.2.1. Memory foam mattresses:

Memory foam mattresses are growing in popularity. They’re created of layers of different of foam that respond to temperature and weight, and are known for comfort since they contour to the specific shape of your body. Memory foam toppers are also accessible.[7]

1.2.2. Latex mattresses:

Latex mattresses are produced either synthetic or natural rubber, and are known for supplying a really strong, bouncy support that’s

Uniform through the bed.[8]

1.2.3. Air mattresses:

Higher-end air beds look as a typical innerspring mattress, but use air filled chambers instead of coils to provide support and are covered by a foam layer on top. Air beds have been used for patients with spinal cord injuries that are lying in bed for quite a long time. So they do not continue to press on the same regions of the body, which helps to prevent skin dysfunction in patients who can not move, they may be fixed.[9]

1.2.4. Innerspring mattresses:

Innerspring mattresses commonly of just the spring core, and the top and bottom upholstery layer.[10]

It consists of two primary section-care or" support layer" and the upholstery or "comfort layer" wrapped in a thick fabric called the licking, innerspring mattresses continue to be the most commonly used. Innerspring mattress consists of: innerspring core, cushioning, upholstery ticking.[11]

1.2.4.1. Innerspring core:

Box spring is a foundation for a mattress, consisting of wire spring elements mounted on a frame. Box spring assembly is an interconnection of coil spring, border wire and top wire assembly contained within a box spring. It has a series of double cone coils in a spring unit, the coil counts is the number that fit in a double or full size mattresses. There are different basic types of spring units [12]:

- Pocket: Pocket coils (individual coils wrapped in fabric) are the most popular and widely used mattress coil type. They provide mostly consistent distribution of support as well as motion isolation. Pricier mattresses often feature a more advanced pocket coil design.
- Continuous coils: is an innerspring configuration in which the rows of coils are formed from a single piece of wire. They work in a hinging effect similar to that of offset coils.
- Bonnell / Open: Bonnell coils or open coils are hour-glass shaped and have a simple design. They are almost always used on low-priced mattresses. They are generally supportive but may have below-average durability/ longevity and isolation.
- Offset: Offset coils are sometime used in mid – to higher – priced mattresses. They are similar to Bonnell coils but have better spring action and support. Some variations have good motion isolation and noise control.[13]

1.2.4.2. Upholster layer (cushioning):

Upholstery layer cover the mattress and provide cushioning and comfort. And it consists of three parts: the insulator, the middle upholstery and quilt.

- **The insulator pad** is put directly on top of the coils to keep the spring from pushing through the padding material or to insulate the upholstery from the core and to absorb the resulted stresses from the motion of the innerspring. The insulator layer made of fiber or mesh or needle punched pad formed from reprocessed rags and is from "$1/8$ to $1/4$" thick to keep the middle upholstery in place. Then a padding material is applied over the insulator before the ticking cover is put on.[14]
- **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, including flexible polyurethane foam (which includes convoluted "egg-crate" foam), Visco-elastic foam, latex foam, felt, polyester fiber, wool fiber and nonwoven fiber pads.
- **The quilt** is the top layer of the mattress. Made of light foam or fibers stitched to the underside of the ticking, it provides a soft surface texture to the mattress and can be found in varying degrees of firmness.

- **The ticking** is the protective fabric cover used to encase mattresses and foundations. It is usually designed to coordinate with the foundation border fabric and comes in a wide variety of colors and styles.[15]

II. EXPERIMENTAL WORK

2.1. Specification of samples under study

The present research is concerned with the nonwoven fabrics which are suitable for using as insulator layer in innerspring mattresses. Nonwoven technique was applied to produce 9 samples; two kinds of textile materials were used: polyester, waste and reinforced waste with woven polypropylene ribbons.

Nonwoven polyester fabrics: made of two types of polyester fibers count [9 den., 15 den.], and two types of fibers melting at [100^{o}C & 130 ^{o}C]. Then the polyester fabrics pass between two hot calendars at 120 ^{o}C to give more bonding and hold the fabric tightly. Table (1) shows the specification of nonwoven polyester fabrics. Nonwoven waste fabrics pass between two hot calendars at 100 ^{o}C whereas melting of polypropylene fibers improve or give more bonding and hold the fabric tightly. Table (2) shows the specification of non woven waste fabrics.

Nonwoven waste fabrics reinforced with woven poly propylene ribbons with plain weave 1/1. Tables (3) and (4) show the specification of waste nonwoven fabrics and specification of woven polypropylene ribbons which used as reinforcement.

Table (1): Specification of nonwoven polyester fabrics

No.	Property	Specification
1	Fiber type	Polyester
2	Fiber length	64 mm
3	Fiber count	9 , 15 den.
4	Web formation	C. L. (cross – laid)
5	Fabric weight	600 gm/m^2
6	Beats/min	500
7	Needle penetration depth (two sides)	10, 12 and 14 mm

Table (2): Specification of nonwoven waste fabrics

No.	Property	Specification
1	Fiber type	Waste
2	Fiber length	20 ,30 , 40 mm
3	Fiber count	3 , 6 , 15 , 25 den.
4	Web formation	C. L. (cross – laid)
5	Fabric weight	800 gm/m^2
6	Beats/min	250
7	Needle penetration depth (two sides)	10, 12 and 14 mm

Table (3): Specification of nonwoven waste fabric reinforced with woven polypropylene ribbons

No.	Property	Specification
1	Fiber type	Waste
2	Fiber length	20 , 30 , 40 mm
3	Fiber count	3 , 6 , 15 , 25 den.
4	Web formation	C. L. (cross – laid)
5	Fabric weight	1250 gm/m^2
6	Beats/min	250
7	Needle penetration depth (two sides)	10, 12 and 14 mm

Table (4): Specification of woven polypropylene ribbons used as a reinforcement

No.	Property	Specification
1	Warp type	Polypropylene
2	Weft type	Polypropylene
3	Warp and weft count	1000 denier
4	Warp and weft set	5 picks/cm, 5 ends/cm
5	Fabric structure	Plain weave 1/1
7	Fabric weight	60 gm/m^2

2.2. Test applied to samples under study

The experimental tests have been achieved in the weave laboratory in the national institute for standards in Haram, Giza in a standard environment (relative moisture: 65±2, temperature 20^{o}C±2).

In order to evaluate the performance properties of the produced samples, the following tests were carried out.

1. Tensile strength and elongation at break in both directions was determined according with (ASTM-D 4595-83) by using Tensile Testing Machine – Tinius Olsen – SDLATLTLAS Model H5KT.
2. Tear resistance was determined according with (ASTM-D 4533-82) by using Tensile Testing Machine – Tinius Olsen – SDLATLATLAS model H5KT.
3. Static puncture was determined according with (EN ISO 12236:1996) by using Tensile Testing Machine – Tinius Olsen – SDLATLATLAS model H5KT.
4. Bursting strength of textile was determined according with (ASTM-D 3787-2001) by using Ball Burst test.
5. Fabric thickness was determined according with (ASTM-D 1777-84) by using Digital Thickness Gauge – SDLATLATLAS.

III. RESULTS AND DISCUSSIONS

Results of experimental tests carried out on the produced samples were presented in the following tables and charts .Results were also statistically analyzed for the date listed and relationships between variables were obtained.

3.1. Tensile strength at break:

Table (5): Tensile strength measurements results in both directions

	Tensile strength kg/cm^2					
Fabric type	Polyester		Waste		Reinforced waste	
Weight	600 gm/m^2		800 gm/m^2		1250 gm/m^2	
Direction / Needles penetration	Length	Width	Length	Width	Length	Width
10 mm	55.8	43.7	15.4	11.6	22	13.8
12 mm	58.6	46.3	17	13	23.8	15.8
14 mm	60.3	48.2	19.5	15.6	25.6	17.6

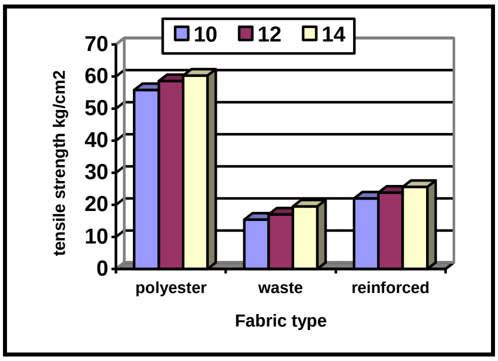

Fig. (1)
Effect of fabric type and needle penetration depth mm on the tensile strength at break in the length direction

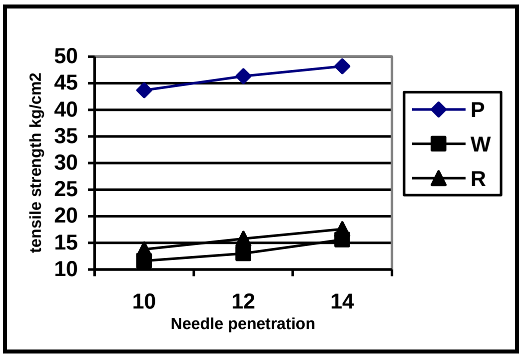

Fig. (2)
Effect of fabric type and needle penetration depth mm on the tensile strength at break in the width direction

3.1.1. Effect of type of materials on the tensile strength at break in both direction:

It is clear from table (5) and figs. (1,2) which is concerned with testing the fabrics produced for the present study that the non woven polyester fabrics have higher tensile strength than the nonwoven reinforced waste where as the non woven waste has the lowest tensile strength. This can be interpreted as the reason is difference between properties of materials and used reinforcement.

3.1.2. Effect of the needles penetration depth on the tensile strength at break in both direction:

It is clear from table (5) and figs. (1,2) that there is direct relationship between the needle penetration depth and samples tensile strength this is due to the increase in needle penetration depth leading to the increase in contact area between fibers and contribute to resistance against tensile which results in increasing the tensile strength at break.

3.2. Elongation at break:

Table (6): Fabric elongation at break measurements results in both directions

	Elongation at break %					
Fabric type	Polyester		Waste		Reinforced waste	
Weight	600 gm/m^2		800 gm/m^2		1250 gm/m^2	
Direction / Needles penetration	Length	Width	Length	Width	Length	Width
10 mm	52.4	41.8	6.2	5.5	9.5	7.2
12 mm	54.3	44.7	8.3	7.2	11.2	9.4
14 mm	56.3	47.2	9.7	8.3	13.4	11.6

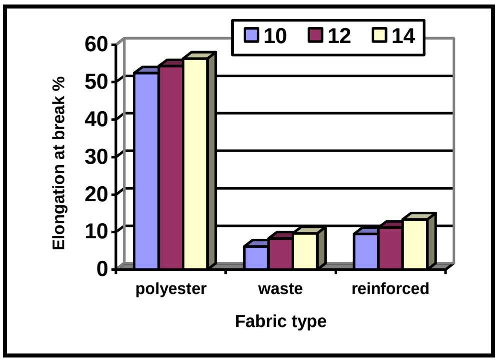

Fig. (3)

Effect of fabric type and needle penetration depth mm on the elongation at break % in the length direction

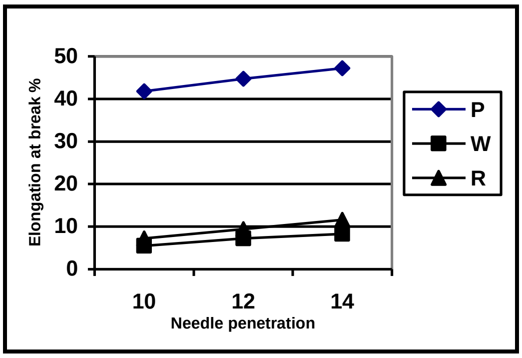

Fig. (4)

Effect of fabric type and needle penetration depth mm on the elongation at break % in the width direction

3.2.1. Effect of type of materials on the elongation at break in both direction:

It is clear from table (6) and figs. (3,4) that the nonwoven polyester fabrics have higher elongation at break than the nonwoven reinforced waste whereas the nonwoven waste has lowest elongation at break this can be interpreted as the reason is the difference between properties of materials and used reinforcement.

3.2.2. Effect of the needles penetration depth on the elongation at break in both direction:

It is clear from table (6) and figs. (3,4) that there is direct relationship between needle penetration depth and samples elongation. This is due to the increase in needles penetration depth leading to the more compacted and merging between the fibers and thereby more elongation for all the types of the samples under study.

3.3. Fabric Tear Resistance:

Table (7): Fabric tear resistance measurements results in both directions

	Tear resistance kg					
Fabric type	Polyester		Waste		Reinforced waste	
Weight	600 gm/m^2		800 gm/m^2		1250 gm/m^2	
Direction / Needles penetration	Length	Width	Length	Width	Length	Width
10 mm	25.8	13.6	6.4	4.2	11.9	9.8
12 mm	27.2	15.8	8.6	5.6	13.2	11.3
14 mm	28.4	16.9	9.2	7.2	14.8	12.6

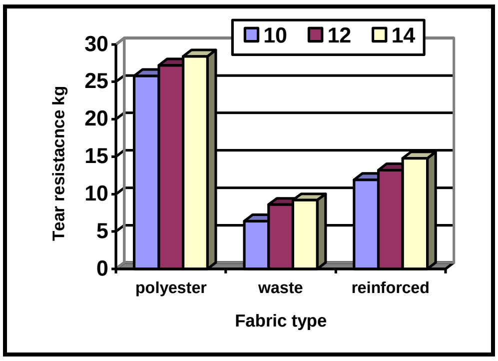

Fig. (5)

Effect of fabric type and needle penetration depth mm on the tear resistance kg in the length direction

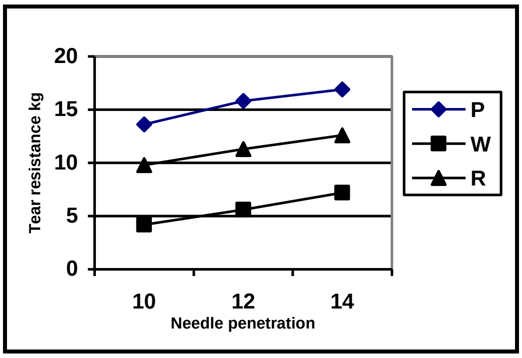

Fig. (6)

Effect of fabric type and needle penetration depth mm on the tear resistance kg in the width direction

3.3.1. Effect of types of materials on the tear resistance in both direction:

It is clear from table (7) and figs. (5, 6) that the nonwoven polyester fabrics have higher tear resistance than the nonwoven reinforced waste where as the nonwoven waste has the lowest tear resistance. This can be explained as the difference between properties of materials and used reinforcement.

3.3.2. Effect of the needles penetration depth on the tear resistance in both direction:

It is clear from table (7) and figs. (5,6) that there is direct relationship between the needle penetration depth and samples tear resistance this can be explained as the increase in needle penetration depth leading to the more compacted and merging between the fibers and there by more tear resistance for all the types of samples under study.

3.4. Puncture Resistance Of Fabrics:

Table (8): Fabric puncture resistance measurements results

		Puncture resistance kg		
Fabric type		Polyester	Waste	Reinforced waste
Weight		600 gm/m^2	800 gm/m^2	1250 gm/m^2
Needles penetration depth	10 mm	28.8	23.2	27.1
	12 mm	30.1	24.6	28.5
	14 mm	31.6	26.3	29.7

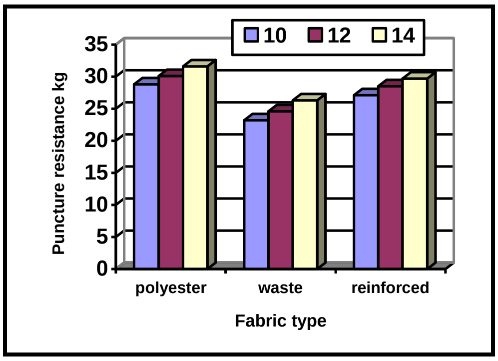

Fig. (7)

Effect of fabric type and needle penetration depth mm on the puncture resistance kg

3.4.1. Effect of types of materials on the puncture resistance:

It is clear from table (8) and fig. (7) That the nonwoven polyester fabrics have higher puncture resistance than the nonwoven reinforced waste whereas the nonwoven waste has the lowest puncture resistance, this can be interpreted as the difference between properties of materials and the used reinforcement.

3.4.2. Effect of the needles penetration depth on the puncture resistance:

It is clear from table (8) and fig. (7) that there is direct relationship between needle penetration depth and samples puncture resistance this can be explained as the increase in needle penetration depth leading to the more compacted and merging between the fibers and there by more puncture resistance for all the types of samples under study.

3.5. Fabric Bursting Strength

Table (9): Fabric bursting strength measurements results

		Bursting strength kg		
Fabric type		Polyester	Waste	Reinforced waste
Weight		600 gm/m^2	800 gm/m^2	1250 gm/m^2
Needles penetration depth	10 mm	129.8	50	96.3
	12 mm	132.5	52.2	98.2
	14 mm	134.2	53.8	100.3

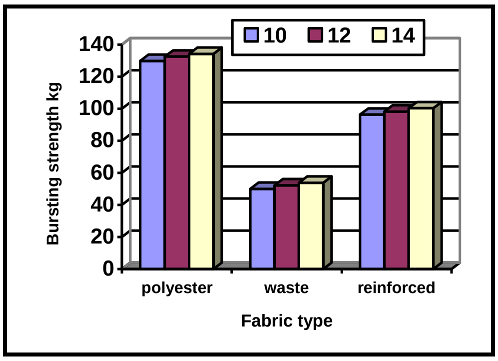

Fig. (8) Effect of fabric type and needle penetration depth mm on the bursting strength kg

3.5.1. Effect Of Types Of Materials On The Fabric Bursting Strength:

It is clear from table (9) and fig. (8) That the non woven polyester fabrics have higher Bursting strength than the nonwoven reinforced waste whereas the nonwoven waste has the lowest Bursting strength, this can be explained as the difference between properties of materials and used reinforcement.

3.5.2. Effect of the needles penetration depth on the fabric Bursting strength:

It is clear from table (9) fig. (8) that there is direct relationship between the needle penetration depth and samples bursting strength this can be explained as the increase in needle penetration depth leading to the more compacted and merging between the fibers and thereby more bursting strength for all the types of the samples.

3.6. Thickness Of Fabric:

Table (10): Fabric thickness measurements results

		Fabric thickness (mm)		
Fabric type		Polyester	Waste	Reinforced waste
Weight		600 gm/m^2	800 gm/m^2	1250 gm/m^2
Needles penetration depth	10 mm	5.3	6.7	9.2
	12 mm	4.6	5.8	8.5
	14 mm	3.8	5.2	7.7

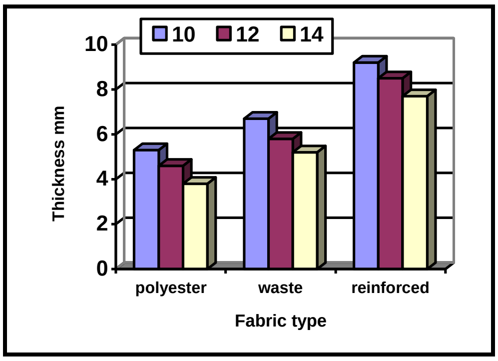

Fig. (9) Effect of fabric type and needle penetration depth mm on the thickness mm

3.6.1. Effect of types of materials on the thickness of fabrics:

It is clear from table (10) and fig. (9) That the nonwoven reinforced waste has higher thickness than the nonwoven waste fabric where as the nonwoven polyester fabrics have the lowest thickness, this can be explained as the difference between properties of materials and used reinforcement.

3.6.2. Effect of the needles penetration depth on the fabric thickness:

It is clear from table (10) and fig. (9) That there is inversely proportional relation exists between the fabric thickness and the needle penetration depth. This can be explained as the increase in needle penetration depth leading to more compacting and merging between the fibers and thereby less fabric thickness for all the types of the samples under study.

IV. CONCLUSION

In this study, samples of non woven fabrics were produced for insulator layer in innerspring mattress by using two types of materials. Many results were reached for example.

- The types of materials and used reinforced have great impacts on the tensile strength, elongation, tear resistance, puncture, resistance, bursting strength and thickness.

- The non woven polyester fabrics have higher tensile strength, elongation, tear resistance, puncture resistance and bursting strength than the reinforced waste where as the nonwoven waste has the lowest.
- The reinforced waste fabric has higher thickness than the nonwoven waste fabric where as the nonwoven polyester fabric has the lowest thickness.
- There is direct relationship between the needle penetration depth and the tensile strength, elongation tear resistance, puncture resistance, bursting strength for all the types of samples under study.
- There is inversely proportional relation between the thickness and the needle penetration depth for all the types of samples under study.

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