



Non-Woven Fabric as a Potential Linen for Synthetic Leather in Upholstery Stuff

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Abstract

The use of artificial leather in the field of upholstery requires the presence of linings that serve as a pillar for these leathers to gain the properties of durability and flexibility necessary for this industry, which calls for manufacturers to use foam on a large scale in the furniture industry. In this research, three synthetic leather samples with thicknesses of 1.01 mm, 1.17 mm, and 1.59 mm underwent lining with two different non-woven materials, that is, needle punch and spun-bonded types, while the third was artificial foam. Lined samples were investigated, aiming to evaluate the best mechanical and physical properties of the nonwoven linen type compared to popularly used artificial foam. Our investigation showed that the best tensile strength and the best punch force resistance are for synthetic leather lined with spun-bonded non-woven of an average free thickness of 1.82 mm and a compression ratio of 3.2%. However, the best fluid absorption is for synthetic leather lined with synthetic foam of a free thickness of 10.28 mm and an 82% compression ratio. This results in encouraging the use of non-woven as a durable material instead of foam when calling for the best tensile strength and punch force resistance.

Subject Areas

Functional Materials

Keywords

Non-Woven, Synthetic Leather, Foam, Linen

1. Introduction

Manufactures for a very long time used to use foam widely in upholstery, but due to some inconvenient reasons related to environmental changes and weak

physical and mechanical characteristics there was a need to search for other materials to take over foam. Non-woven fabrics were thought to be a nominee for this job.

In this respect, the Characterization of some non-woven products used in the automotive industry showed that non-woven products using the method of mechanical cohesion are very interesting in the automotive industry. [1] However, thermal insulation in car upholstery was achieved by making a product consisting of several layers with a structure that has the ability to reserve air between layers to enhance isolation. [2]

The general trend during the last decade of the twentieth century deals with the technology of non-woven products, where the discovery of these textiles led to a large and strong economic boom that helped to open new horizons and areas to expand the leaders of their uses, as these non-woven products were characterized by low costs and distinguished natural and mechanical properties in the upholstery field, like the ability of non-woven fabrics to absorb liquids, retain heat, and have high flexibility, in addition to the distinction of tensile and elongation properties and their resistance to fungal infection. [3] Accordingly, these features of non-woven fabrics encouraged our research team to use this type of fabric in lining artificial leather used in the upholstery and furnishings industry, where we expect to obtain a new material distinct in its natural and mechanical properties from those available in this industry of materials lined with foam.

2. Results and Discussion

Thermal bonding is a widely used method for bonding nonwoven webs. It takes advantage of the fact that fibers or filaments made from thermoplastic polymers can melt, flow, and then re-solidify upon cooling. This method works according to the following sequences

- 1) Local Heating: In the thermal bonding process, fibers are locally heated to their softening temperature.
- 2) Bond Formation: Once softened, the fibers adhere to each other, creating bonds within the web.
- 3) Cooling and Solidification: After bonding, the fibers cool down and solidify, resulting in a cohesive nonwoven structure. This method offers several advantages, including high production rates due to bonding occurring at high speeds using heated calendar rolls or ovens¹. It has been successfully applied to various thermoplastic fibers in nonwoven manufacturing.

2.1. Synthetic Leather Samples with Thicknesses of 1.17 mm

2.1.1. Tensile Strength

Analyzing the mechanical properties recorded in **Table 1**, it becomes clear to us that in the case of the artificial leather lining, using the mechanical needle stitching method, the lowest recorded value of the tensile strength was 76.60 kg at a thickness of 2.84 mm, and the highest value of the tensile strength was 80.60 kg at a thickness of 4.90 mm, as is evident. We know that the thicker the lining,

the greater the resistance of the samples to cutting and tearing.

When using a lining made using the thermal bonding method for fibers, the phenomenon of increasing tensile strength with increasing thickness of the samples was confirmed, as the lowest value of the tensile strength reached 84.00 kg at a thickness of 1.32 mm and the highest value of tensile strength was 165 kg at a thickness of 1.73 mm. As for the third type of lining used, which is a synthetic sponge, the phenomenon of increasing tensile strength continued with increasing sample thickness, as the lowest value of tensile strength reached 68.60 kg at a thickness of 2.21 mm and the highest value of tensile strength was 70 kg at a thickness of 9.70 mm. From the above it is clear to us that the highest value of force resistance Tensioning and cutting when using a non-woven fabric lining made using the thermal bonding method for fibers, as this is due to the stability of the sample dimensions as a result of the strong adhesion of the filaments under the influence of thermal pressure during the manufacture of this type of non-woven fabric, as the filaments are completely organized, making them more resistant to cutting.

It is also noted that there is an internal direct relationship between thickness and tensile strength for each type of lining used, but there is no relationship between thickness and tensile strength for the different types of lining. We note that the non-woven fabric lining (thermal bonding) was the thinnest sample and had the highest resistance to tensile strength. It is also noted that The tensile strength of the sample in the presence of a lining is higher than in the case of leather without a lining. Accordingly, the tensile strength of the non-woven

Table 1. The relationship between the physical and mechanical properties of the leather sample thickness 1.01 mm.

Non-woven Lining type	Free thickness (mm)	Thickness under pressure (mm)	Compression ratio (%)	Specific weight (gm/cm ³)	Tensile strength (Kg/cm ²)	Punch force (Kg/cm ²)	Fluid absorption (%)
Needle punch	2.84	2.13	25.00	27.50	76.60	46.00	302.69
	3.54	2.67	24.57	24.91	77.30	50.49	363.61
	3.56	2.76	22.47	25.24	77.60	51.50	384.17
	4.75	3.75	21.00	25.75	79.30	58.00	401.76
	4.90	4.14	15.55	29.20	80.60	62.00	402.64
Spun bonded	1.32	1.26	4.06	50.81	84.00	63.50	71.80
	1.42	1.30	7.00	49.47	86.00	69.00	72.50
	1.54	1.48	3.89	52.57	132.00	70.10	77.40
	1.73	1.67	3.00	51.04	165.00	76.00	85.11
Industrial sponge	2.21	1.26	45.00	28.41	68.60	41.50	342.99
	5.62	1.64	70.79	11.26	69.60	42.00	376.94
	9.70	1.60	83.50	8.73	70.00	44.00	449.85
Lining free leather	1.01	0.91	9.80	50.79	68.00	42.00	86.25

fabric lining (thermal bonding) > the non-woven fabric lining (mechanical needle stitching) > the sponge lining > the leather without a lining as represented by the graphic **Figures 1(a)-(c)**.

2.1.2. Punch Force

However, from the results recorded in **Table 1**, it is clear that the greater the thickness of the lining, the greater the resistance of the samples to penetration, and when using a non-woven fabric lining (thermal bonding), the phenomenon of increasing the value of the punch force continued with the increase in the thickness of the samples, as the lowest value reached 63.50 kg at a thickness of 1.23 mm and the highest value of the punch force was 76 kg at a thickness 1.73 mm. As for the synthetic sponge lining, the same phenomenon was repeated, which is that the resistance of the sample to penetration increased with increase in thickness of the lining, where the lowest value was 41.50 kg at a thickness of 2.21 mm, and the highest value for penetration force was 44 kg at a thickness of 9.70 mm. From the above, it is clear to us that the highest sample resistant to tearing by puncture (penetration) is the one lined with non-woven fabric made using the method of thermal bonding of fibers, and that the least resistant samples are the samples lined with synthetic sponge. This is due to the fact that non-woven fabrics are distinguished from sponges by the increased arrangement of the filaments in a vertical direction. It impedes the movement of hairs in the

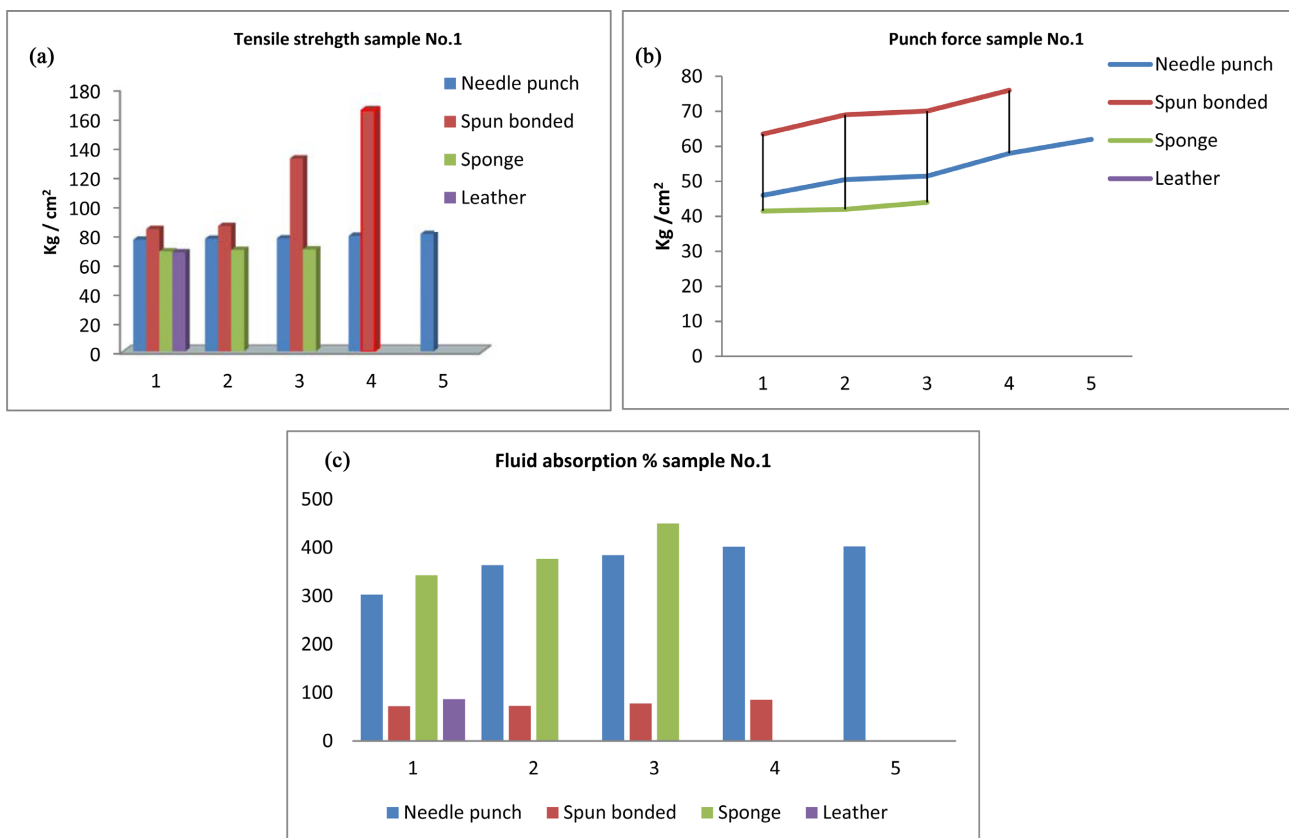


Figure 1. Tensile strength, punch force and fluid percent of the leather sample thickness 1.01 mm.

horizontal direction, which increases the resistance of these fabrics to tearing by penetration. Also, the resistance of non-woven fabric (thermal bonding) to penetration is higher than the resistance of non-woven fabric (mechanical needle stitching) due to the accuracy of the hairs of the thermal bonding fabric and the regularity of its hairs compared to the hairs of non-woven fabric (mechanical needle stitching). It is also noted that there is an internal direct relationship for each type of lining. There is a relationship between thickness and penetration strength, but there is no relationship between thickness and penetration for the different types of lining, as we find that the samples lined with thermal bonding fabric are the thinnest samples and have the highest resistance to punctures by penetration. Indeed, **Figures 1(a)-(c)** show that the punch forces of the thermal bonding fabric lining > the lining of the mechanical needle insertion fabric > the synthetic sponge lining > leather without lining.

2.1.3. Fluid Absorption

On the other hand, we find that it is very important to investigate the relationship between fluid absorption and the different types of lining under study. In the case of using the non-woven mechanical needles lining, the lowest value for absorbing liquids was 302.69% at a thickness of 2.84 mm and the highest absorption rate of 402.64% at a thickness of 4.90 g, where the absorption rate of liquids increases with increasing the thickness of the lining, and in the second lining made with thermal bonding cloth, the phenomenon of increasing the percentage of absorption of liquids was confirmed by increasing the thickness of the samples, as it reached the lowest value of 342% at a thickness of 2.21 mm and the highest value of 449.85% at the thickness of 9.70 mm.

2.1.4. Statistical Analysis

These results confirmed the statistical significance, as, where the correlation coefficient (R) reached 0.90 in the case of the mechanical stitching lining, 0.99 in the case of the thermal bonding lining, while the value of (R) in the sponge lining reached 0.95. There are also statistically significant differences between tensile strength and thickness, where the significance of the (R) reached (6.83×10^{-25}) for the lining made with mechanical needle stitching, 1.29×10^{-15} for the lining made with thermal bonding, and 2.58×10^{-10} for the lining made of sponge at the level of significance (< 0.05). On the other hand, we found a statistical significance value of (R) equals 0.99 in samples lined with non-woven fabric, while in samples lined with synthetic sponge, the value of (R) was 0.97.

Statistical studies of the fluid absorption showed the existence of statistical significance, where the value of (R) was 0.96 when using non-woven fabric (mechanical needles) as lining, 0.93 in the case of thermal bonding and sponge because there is a strong direct link between the thickness and the percentage of fluid absorption., where the results were significant 1.69×10^{-23} (mechanical needles), 1.81×10^{-13} (thermal linkage) 102×10^{-11} (foam) at the level of significance (< 0.05). We conclude that there is a strong direct correlation be-

tween tensile strength, the resistance of the samples to tear by penetration hole, and thickness of the samples. Also, statistical analysis confirmed that there is a strong direct correlation between the thickness of the foam linens and fluid absorption.

2.2. Synthetic Leather Samples with Thicknesses of 1.17 mm

2.2.1. Tensile Strength

According to the study results of the sample, 1.17 mm synthetic leather lining with the same non-woven species and synthetic sponge, study analysis declares that the highest samples resistant to cutting when pulling are those samples lined with non-woven fabric “thermal bonding”, due to the accuracy of the filaments, the strength of their adhesion and the intensity of their regularity in the layers of non-woven fabric made by the method of thermal bonding of fibers. It is also noted that there is an internal direct relationship for each type of lining between the thickness and tensile strength, but there is no relationship between the thickness and tensile strength of the different types of linings, **Figures 2(a)-(c)**. So, we note that the lining of the thermal bonding cloth was less thick between the types of linings and had the highest resistance to cutting when pulling, **Table 2**.

The cutting resistance when stretching the lining of the non-woven fabric (thermal bonding) > the resistance of the fabric (inserting mechanical needles) > the resistance of the lining of the foam > leather without lining.

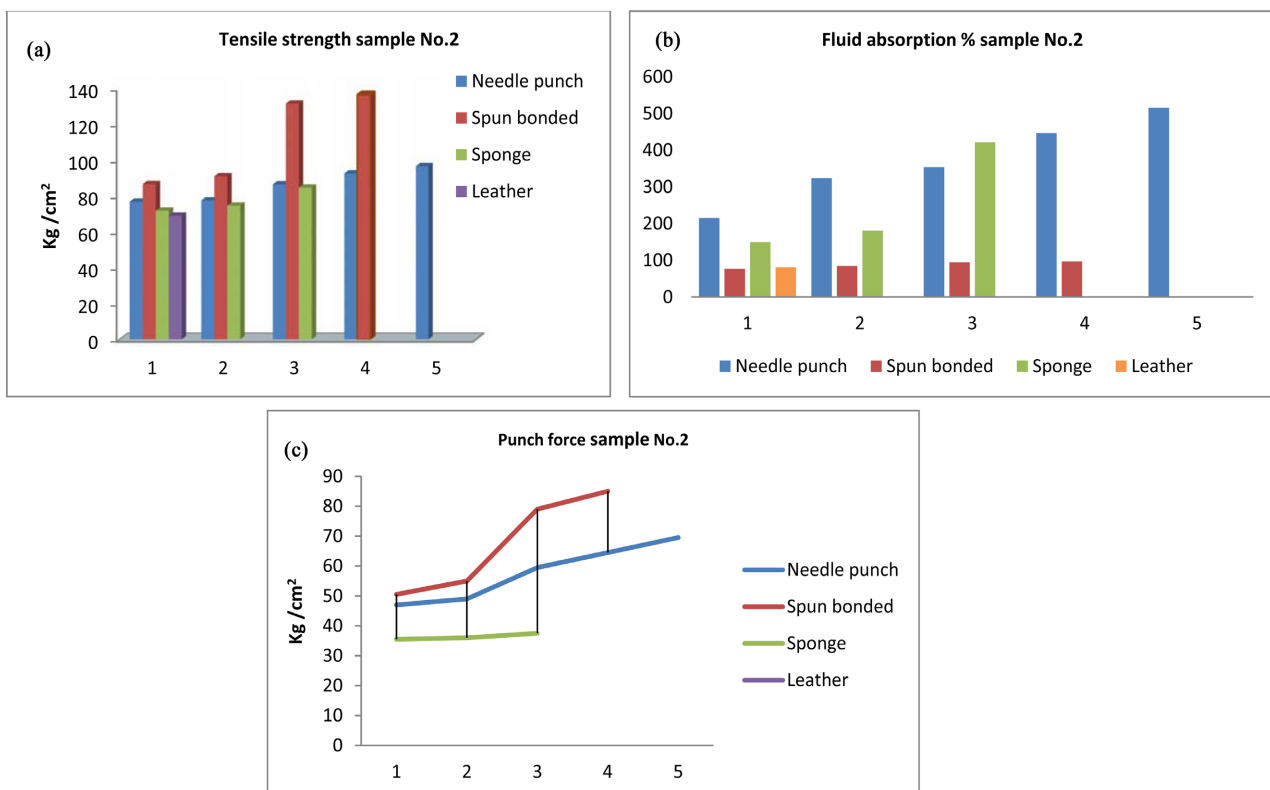


Figure 2. Tensile strength, punch force and fluid percent of the leather sample thickness 1.17 mm.

Table 2. The relationship between the physical and mechanical properties of the leather sample thickness 1.17 mm.

Non-woven Lining type	Free thickness (mm)	Thickness under pressure (mm)	Compression ratio (%)	Specific weight (gm/cm ³)	Tensile strength (Kg/cm ²)	Punch force (Kg/cm ²)	Fluid absorption (%)
Needle punch	3.39	2.58	23.89	26.25	76.80	47.00	214.90
	3.61	2.76	23.54	26.31	77.50	49.00	323.67
	3.69	2.88	22.00	27.47	86.50	59.50	354.12
	4.26	3.44	19.17	25.75	92.60	64.50	446.50
	4.70	3.85	18.08	25.38	96.60	69.50	515.47
Spun bonded	1.56	1.45	4.50	45.00	86.60	50.49	76.45
	1.57	1.50	4.10	49.00	91.00	55.00	84.78
	1.84	1.76	3.90	50.65	131.60	79.00	94.43
	1.92	1.85	3.20	51.09	136.60	85.00	96.98
Industrial sponge	2.40	1.37	42.91	26.50	71.76	35.50	149.42
	5.71	1.66	70.92	11.38	74.67	36.00	180.79
	9.86	1.80	81.74	7.52	84.67	37.50	421.42
Lining free leather	1.17	0.69	41.17	46.58	69.00	37.00	80.85

2.2.2. Punch Force

The Penetration resistance of thermal bonding fabric lining > penetration resistance of mechanical needle insertion fabric lining > resistance of foam lining > unlined leather. This is due to the distinction of non-woven fabrics from sponges by increasing the arrangement of the hairs in the vertical direction, which hinders the movement of the bristles in the horizontal direction, which makes the lining of these fabrics more able to resist tearing by piercing. In addition, increasing the arrangement and accuracy of the bristles of the thermal bonding fabric, make it the highest sample resistant to penetration.

There is also an internal direct relationship for each lining type between thickness and resistance of samples to penetration and there is no relationship between sample thickness and liner types, **Figures 2(a)-(c)**.

2.2.3. Fluid Absorption

By analyzing **Table 2** and **Figures 2(a)-(c)**, we find that the percentage of fluid absorption increases with increasing the thickness of the lining when using non-woven fabric made by inserting mechanical needles as a lining, where the lowest value was 214.90% at a thickness of 3.39 mm and the highest value of 515.47% at a thickness of 4.70 mm, and this phenomenon was confirmed when using non-woven fabric “thermal bonding” as a lining, where the lowest absorption rate of liquids was 76.45% at a thickness of 1.56 mm and the highest percent of 96.98% at a thickness of 1.92 mm. While the phenomenon was repeated when using foam as a lining, the percentage of fluid absorption increased by increasing the thickness of the lining. Foam had the lowest value of 149.42% at a thickness

of 2.40 mm while the highest value was 421.42% at a thickness of 9.86 mm.

From that, it is clear to us, that the high percentages of fluid absorption and the convergence of values for each of the samples lined with synthetic foam and samples lined with non-woven fabric by inserting mechanical needles, as the ratio in these two linings is higher than the samples lined with non-woven fabric (thermal bonding) due to the correlation of the percentage of fluid absorption with the number of spaces inside the material and the irregularity of its composition molecules.

When used, this fabric increases its ability to absorb liquids in a way that exceeds the strength of the foam used as a lining to absorb liquids. As can be seen from **Figures 2(a)-(c)**, where we note that the absorption rate of liquids in the needle insertion fabric > the absorption rate of liquids in the foam > the percentage of absorption of liquids in the thermal bonding fabric > the percentage of absorption of liquids in the synthetic leather without lining.

It is noted that there is an internal direct relationship between the thickness and the percentage of fluid absorption for each type of lining, and there is no direct relationship between the thickness and the types of linings, as the absorption of liquids increases when the thickness of the lining decreases when comparing the non-woven fabric (insertion of mechanical needles) and foam.

2.2.4. Statistical Analysis

This confirms the existence of statistical significance between thickness and tensile, where the value of the correlation coefficient (R) is 0.94, 0.99 in the case of lining non-woven fabric made by stitching needles and made by thermal bonding respectively, where there is a strong direct correlation that is close to being fully correlated in the case of thermal bonding cloth, while the value of t was 0.97 when using sponge as lining. There are also significant statistical differences, where the significant results were 6.83×10^{-25} (mechanical needles), 1.29×10^{-15} (thermal bonding), 2.58×10^{-10} foam at the level of significance (< 0.05). This is confirmed by the existence of statistical significance, as the value of t was 0.99 in samples lined with non-woven fabric, while in samples lined with synthetic foam, the value of R, was 0.97, where there is a strong direct correlation between the thickness of the samples and the resistance of the samples to tear by penetration hole.

There are also statistically significant differences, where the results were significant 1.07×10^{-22} for the lining of the mechanical needle stitching cloth and 1.77×10^{-20} (thermal bonding), 1.41×10^{-13} (synthetic sponges) at the significance level (< 0.05).

This confirms the existence of statistical significance, where the value of R, was 0.96 when using non-woven fabric (mechanical needles) as lining, 0.93 in the case of thermal bonding fabrics and foam because there is a strong direct link between the thickness and the percentage of fluid absorption.

There were also statistically significant differences, where the results were significant 1.69×10^{-23} (mechanical needles), 1.81×10^{-13} (thermal linkage) $102 \times$

10^{-11} (foam) at the level of significance (< 0.05).

2.3. Synthetic Leather Samples with Thicknesses of 1.59 mm

2.3.1. Tensile Strength

The phenomenon of increased resistance of samples to cutting when tightening was confirmed. When using non-woven fabric (heat bonding) as a lining, the resistance of the samples to cutting increases when tightening with increasing the thickness of the lining, **Table 3**. It is noted that there is an internal direct relationship between the thickness and tensile strength of each type of lining and there is no relationship between thickness and tension between the types of linings, where we find that the lining of the thermal bonding cloth is the least thick and the highest resistance to cutting when pulling, while the sponge lining is the highest thickest linings and the least resistant to cutting when pulling. As can be seen from **Figures 3(a)-(c)**.

2.3.2. Punch Force

From the above, it is clear that the samples lined with non-woven fabric made by thermal bonding of fibers are the highest resistant samples to tear by puncture (penetration). And that the sponge as a lining is the least resistant sample to penetration due to the property of the installation of non-woven fabric and different from the installation of sponges, where the arrangement of the hairs increases in the vertical direction, which hinders the movement of the hairs in a horizontal direction to raise the resistance of the material to the hole and notes

Table 3. The relationship between the physical and mechanical properties of the leather sample thickness 1.59 mm.

Non-woven Lining type	Free thickness (mm)	Thickness under pressure (mm)	Compression ratio (%)	Specific weight (gm/cm ³)	Tensile strength (Kg/cm ²)	Punch force (Kg/cm ²)	Fluid absorption (%)
Needle punch	3.40	2.57	24.30	31.02	63.00	35.00	266.00
	3.93	3.02	23.17	33.02	82.00	45.00	262.00
	4.00	3.12	22.11	32.62	87.00	48.00	265.00
	4.68	3.79	19.07	29.23	92.00	50.00	269.80
	5.20	4.36	16.15	29.01	96.00	60.00	277.60
Spun bonded	1.62	1.55	3.98	59.44	58.00	48.00	56.26
	1.73	1.66	3.65	58.72	61.00	48.00	57.68
	2.65	2.60	2.63	45.56	127.00	63.00	58.01
	2.67	2.61	2.18	44.08	151.00	77.00	59.90
Synthetic sponge	2.83	1.54	45.80	32.45	49.50	34.00	328.23
	6.25	1.81	71.00	15.26	47.00	39.00	341.30
	10.28	1.85	82.00	9.94	54.00	40.00	496.48
Lining free leather	1.59	1.41	11.32	79.72	48.00	28.00	66.40

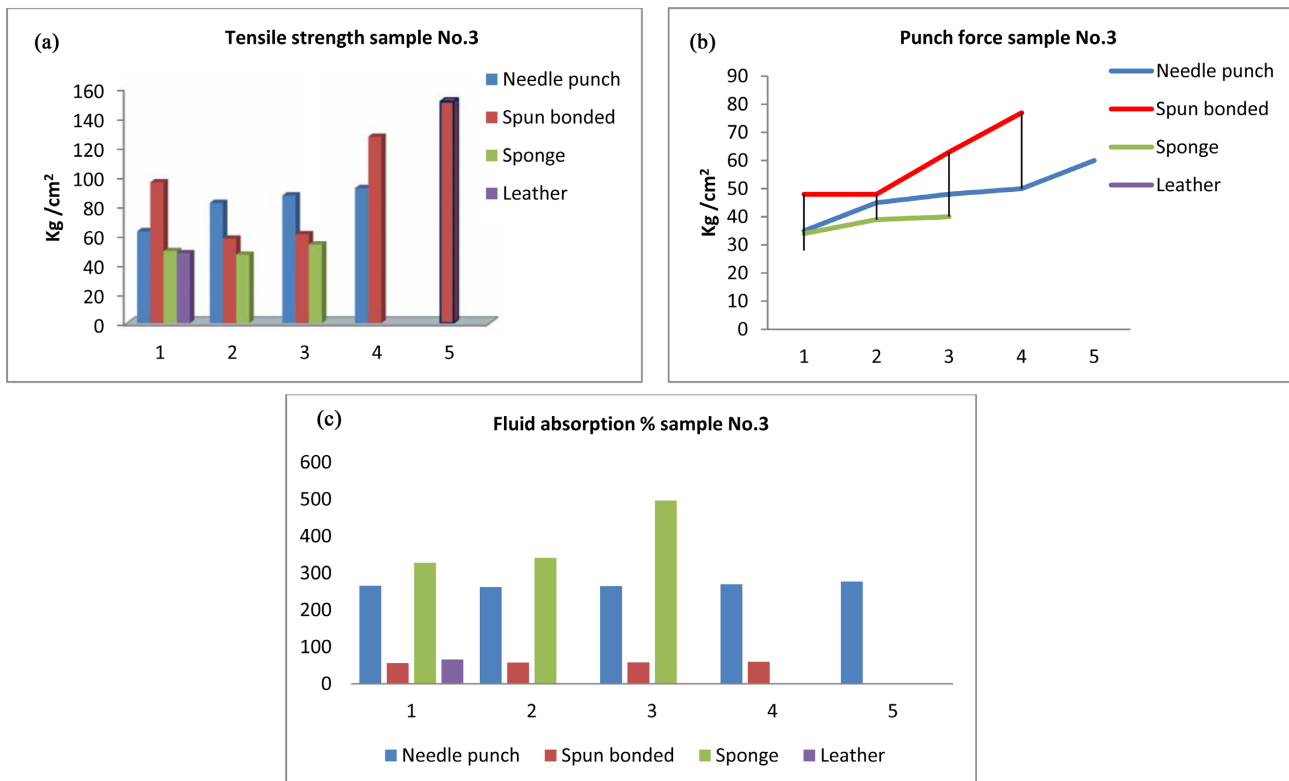


Figure 3. Tensile strength, punch force and fluid percent of the leather sample thickness 1.57 mm.

that the non-woven fabric “thermal linkage” is characterized by accuracy and increased arrangement of the hairs to give the highest resistance values.

It is noted that there is an internal direct relationship for each. It is noted that there is an internal direct relationship for each type of lining between the thickness and penetration resistance and there is no relationship between the thickness and penetration resistance of all linings, as the study showed that the thinner samples lined with thermal bonding fabric are the highest value in tensile strength as shown in **Figures 3(a)-(c)**, that the resistance of thermal bonding lining samples > the resistance of needle insertion samples > foam lined samples > leather samples without lining.

2.3.3. Fluid Absorption

Samples lined with artificial foam are the highest absorbing samples of liquids due to the presence of interstitial spaces and gaps within the structural structure of the sponge material, which allows it to absorb a greater amount of fluid within the folds of their structure greater than the capacity of non-woven fabric. It is also noted that the fabric woven in the manner of inserting needles with spaces between the layers that make up the randomness of the filament mat, the ability of these fabrics to absorb liquids is greater than the ability of thermal bonding fabrics as shown in **Figures 3(a)-(c)**.

The percentage of fluid absorption of foam linings > the percentage of fluid absorption of needle insertion fabrics > the percentage of fluid absorption of

thermal bonding fabrics > the absorption rate of leather without lining. However, we note the existence of an internal direct relationship between the thickness and the percentage of fluid absorption for each type of lining and there is also a direct relationship between the types of linings as the lining of the foam represents the highest thickness linings and the highest absorption of liquids.

2.3.4. Statistical Studies

Tensile strength of non-woven fabric (thermal bonding) > tensile strength of mechanical needle insertion fabric > tensile strength in the foam lining > tensile strength of leather without lining. This confirms the existence of statistical significance, as the value of the correlation coefficient R, was 0.90 in the case of using the lining of non-woven fabric (inserting mechanical needles) 0.98 when using thermal bonding fabric and 0.91 in the sponge lining.

This confirms the existence of statistical significance, where the value of R, was 0.97 for leather samples lined with non-woven needles, 0.99 for leather samples lined with non-woven fabric thermal linkage, while the value of R, was 0.84 for samples lined with foam, which indicates a strong direct correlation between the degrees of thickness and the strength of the resistance of the samples to penetration. There are also statistically significant graphic differences between the thickness and the strength of penetration resistance, where it was significant results, 1.07×10^{-22} for mechanical stitching, 1.77×10^{-20} (thermal bonding), and 1.41×10^{-13} foam at the significance level of < 0.05 .

There are statistically significant graphical differences between the thickness of the different types of linings and the percentage of absorption of liquids, where the results were significant 1.69×10^{-23} (needles), 1.81×10^{-13} (thermal bonding) 1.02×10^{-11} (foam) at the level of significance < 0.05 .

3. Conclusion

Our investigation showed that the best tensile strength and the best punch force resistance are for synthetic leather lined with spun-bonded non-woven of the average free thickness of (1.82 mm) and (3%) compression ratio. However, the best fluid absorption is for synthetic leather lined with synthetic sponge of the free thickness of (10.28 mm) and (82%) compression ratio, **Table 4**.

Table 4. The best mechanical properties in relation to the physical properties.

Non-woven Lining type	Free thickness (mm)	Thickness under pressure (mm)	Compression ratio (%)	Specific weight (gm/cm ³)	Tensile strength (Kg/cm ²)	Punch force (Kg/cm ²)	Fluid absorption (%)
Spun bonded	1.73	1.67	3.00	51.04	165.00	-----	-----
	1.92	1.85	3.20	51.09	-----	85.00	-----
Synthetic sponge	10.28	1.85	82.00	9.94	-----	-----	496.48

4. Material and Methods

4.1. Materials and Suppliers

Testing is carried out at a material testing laboratory—textile engineering laboratory in the National Research Center of Egypt.

Non woven	Trade mark	Model number	pattern	composition	Specifications	Origin
Stitch bonded	sunshine	5603129000	plane	100% polyester	20 - 50 (gm/cm ³)	China
Spun bonded	sunshine	JH231707	dot	100% polypropylene	50 - 100 (gm/cm ³)	China
Neoprene foam	unbranded	-	smooth	Synthetic foam	2 - 10 mm thickness	UK

4.2. Methods

4.2.1. Punching Test

In this study, a new approach for simulating fabric punching under biaxial stress was proposed. A spike punched the sample, which was stretched in the X-Y plane depicts the test sample geometry. The value of (a) was chosen to be 25 mm. **Figure 4** shows how the sample is grabbed in the X and Y axes. Three samples

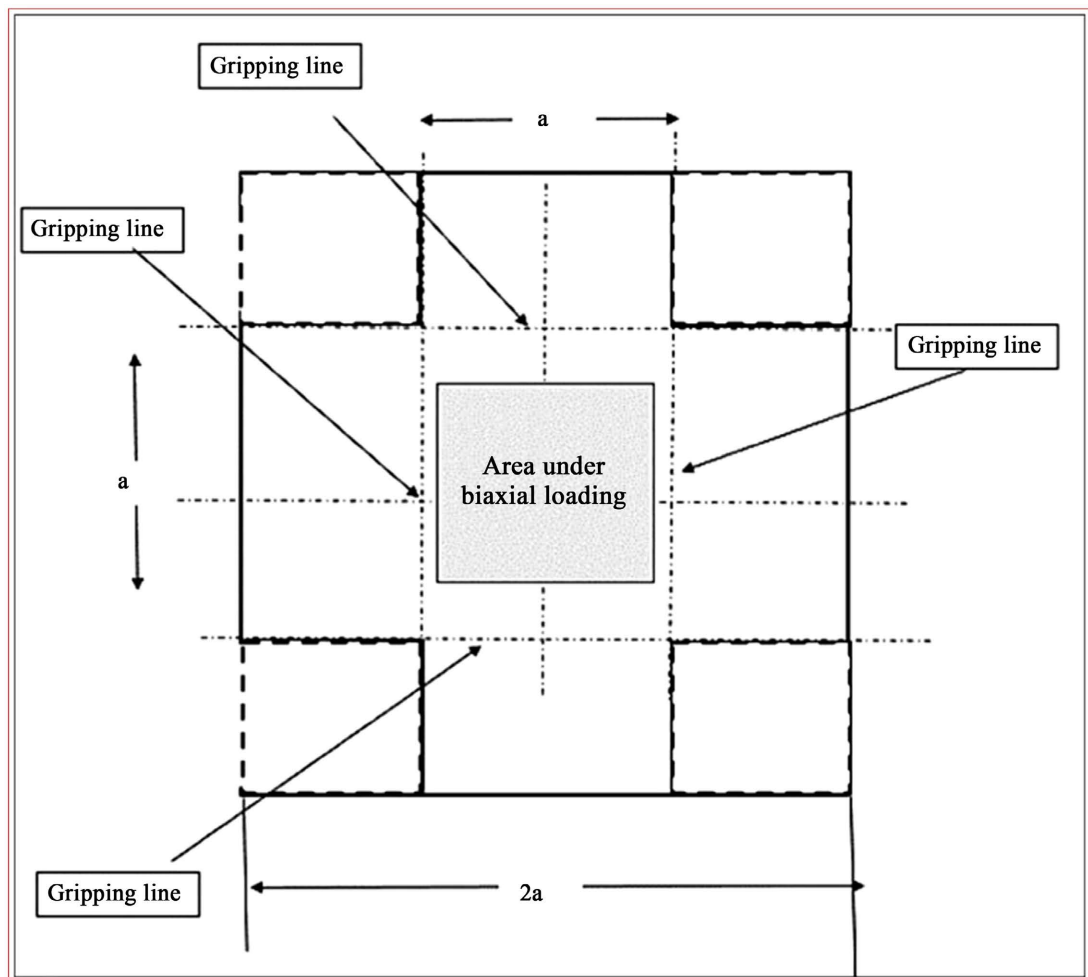


Figure 4. Fabric sample divisions.

from each fabric were evaluated, and the average values were given. [4]

The main aim of using the designed fixture was to be able to run the biaxial extension on the fabric before applying the punching force under predetermined pre-tension (F_x and F_y) in the X or Y direction. The fabric sample was fixed into a special attachment in such a way that the punching force caused biaxial stress during the puncher penetration. The initial pre-tension in both directions X and Y-axis (F_x and F_y) can be adjusted, as illustrated in **Figure 5**.

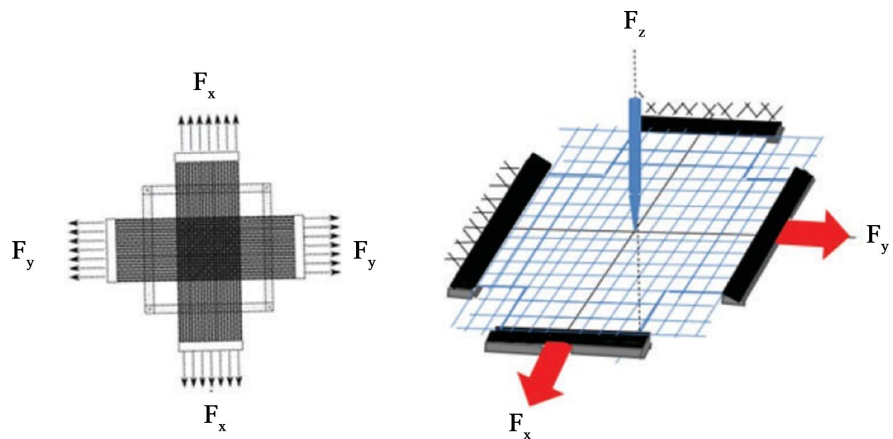


Figure 5. Fabric sample under punching.

The sample holder was placed on the lower jaw of the universal material testing machine as shown in **Figure 6(a)**. The upper jaw moves downwards at the constant speed of 100 mm/min, pushing the puncher through the sample. The load-extension curves of all tested fabrics were recorded and analyzed. In the existing set-ups, used to study the punching performance of the fabrics, the value of the pre-tension cannot be defined. In the suggested design, the value of the pre-tension can be controlled and continuously measured during the punching process. In order to measure the pre-tension, one of the jaws in the X and Y axis was supported on a load cell. The tension value was displayed on the load indicator, **Figure 6(b)**. This clamping system could effectively eliminate the slippage of the tested samples during the punching by the blade.

4.2.2. Tearing Strength Tests

The tensile testing is the universal testing machine (ASTM D638). A rectangular specimen is cut in the center of a short edge to form a two-tongued (trouser-shaped) specimen, in which one tongue of the specimen is gripped in the upper jaw and the other tongue is gripped in the lower jaw of a tensile testing machine, **Figure 7**. The separation of the jaws is continuously increased to apply a force to propagate the tear; at the same time, the developed force is recorded. The force to continue the tear is calculated from an autographic chart recorder. [5]

Fluid absorption test

The demand wet ability test as modified by Miller and Tyomkin, was used in this investigation. The amount of weight loss indicated by the recording balance

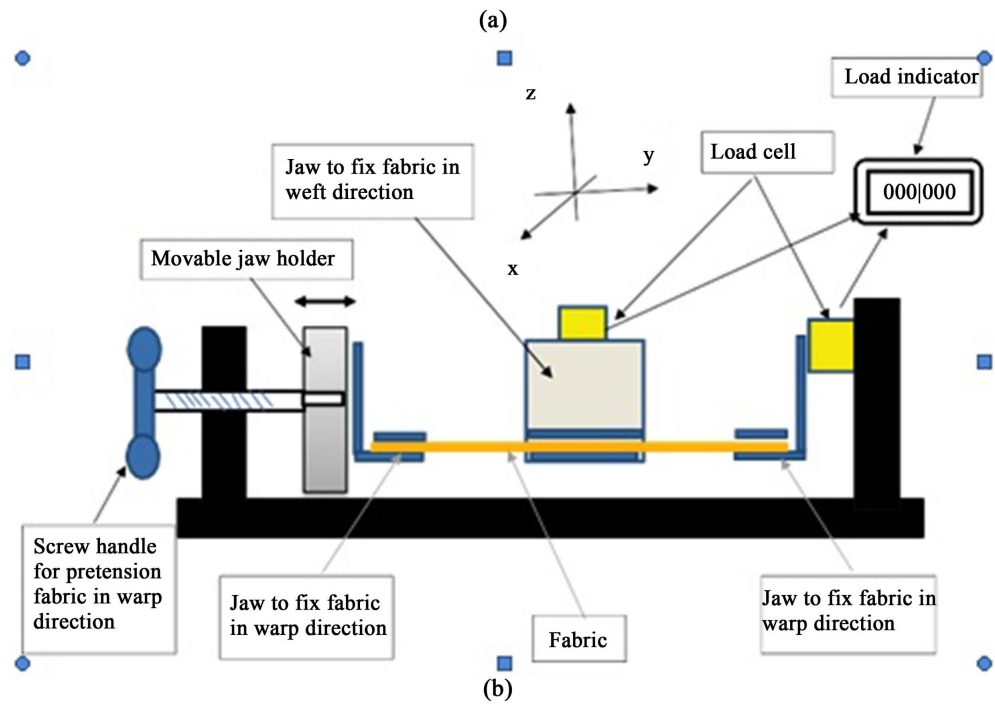


Figure 6. Sample holder setup for fabric punching test.

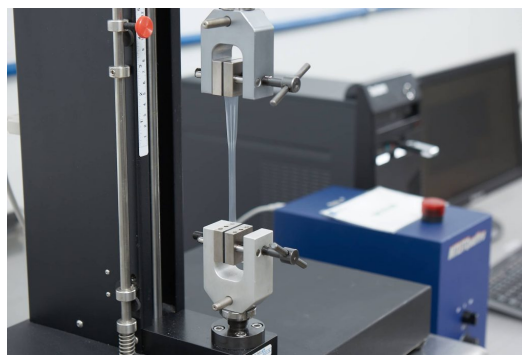


Figure 7. ASTM D882 tensile strength test.

was recorded every 5 seconds for 1 min. and then every 15 seconds up to 20 min. [6]

Statistical Analysis

Statistical significance is a crucial concept in hypothesis testing. It helps researchers determine whether observed differences or relationships in data are likely due to chance or if they represent true effects. In this study we use Test Statistic and R-value, the R-value represents the probability of observing results as extreme as those in the data, assuming the null hypothesis is true. A low R-value (typically ≤ 0.05) indicates statistical significance, suggesting that the observed effect is unlikely due to chance alone.

Conflicts of Interest

The authors declare no conflicts of interest.

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