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Enhancement of the aesthetics appearance and softness of knitted spacer fabric.

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Abstract

With the advances in textile technology and manufacturing methods, the textile industry is witnessing a revolution in technical textile fabrics. These innovative fabrics are entering the market and competing successfully due to their unique properties and added value. Knitted spacer fabric is one of those products that are desirable for their high compression resistance properties as well as the high air permeability, durability and distinguished thermal conductivity. These textiles have been widely used as a replacement for conventional cushions, and used as cover fabrics for seats in vehicles, as well as a variety of other applications This study aims to achieve an improvement in softness of handle and aesthetic appeal by creating a 'composite' of knitted spacer fabric and a Tencel nonwoven fabric..

Key words*: spacer fabric, carded web, compression/recovery, mechanically integrating*

Introduction

Piled surface fabrics are intensively used as a cover fabric for seats in many application such as automobile seat upholstery, domestic upholstery and other areas such as cover fabric for seats in cinema, theater, public transportation and airplane [1]. This is due to the comfort properties provided by those fabrics demonstrated by the moisture absorbency properties of the fabric due to the pile on the surface [2], beside the psychological and aesthetic comfort as the fabric provides a unique aesthetic and good handle properties due to the softness of the surface. The piles fabric still lack other comfort properties in both thermal and tactile comfort, such as poor air permeability and air circulation which significantly affect the thermal and physiological comfort besides the poor compression recovery properties that are required in seat cover fabric. Therefore cushion materials (foams) are used beneath the cover fabric providing the compression properties required to obtain the compression behavior generally desired [3].

Throughout the past years the use of technical textiles has significantly increased and witnessed a remarkable growth as these fibrous materials have capabilities to substitute some conventional materials due to their added value and enhanced properties [4]. Spacer fabric figure.4 is considered a technical textile and is used in many applications including the substation of many of the currently used conventional materials such as polyurethane (PU) foams that are used as an additional layer beneath the cover fabrics used in products such as car, bus and train seats, wheel-chairs, sofas and mattresses as a replacement of foam [5]. Due to the additional unique properties of knitted spacer fabric such as high air permeability, thermal conductivity, water-vapor permeability and moisture management as well as its mechanical properties demonstrated in high strength, tear and abrasion resistance, and the unique advantage of high compression resistance of the fabric, hence the spacer fabric is considered as a suitable and desired replacement to the above mentioned pile products due to the improvement in the knitted spacer characteristics [1].

Taking this approach has led to impact on the air permeability as well as the moisture management due to the number of layers used to combine the soft handling, compression resistance and thermal comfort

[3]. The properties provided by the spacer fabric such as the high breathability, moisture management, and stability, supporting, and shaping [3] cannot be obtained by use of single layered fabrics.
Beside the desirable properties required for the scope of application discussed cannot be provided by a knitted spacer fabric due to the shortfall in the handle aspect which is viewed by the end users as unappealing and required for sort handle, comfort and aesthetic appeal. These characteristics are all important when assessing the fabric and development decisions when selecting the right fabric for the end use (Collier and Epps, 1999) [7].
Currently there are several methods to combine both piled fabric and spacer fabric through sewing, laminating or use of adhesive, but those methods are accompanied with drawbacks. For example combination through laminating or adhesive lead to changes and loss of the properties such as significant reduction in air permeability and breathability and reduced moisture absorbency. There would also be a loss in air circulation of the 'compromised' spacer fabric. Besides these losses adhesion leads to less stretch ability which changes the collective properties of the composite and reduces benefits obtained by the spacer fabric [3]. In addition spacer fabrics have a tendency when used in combination with a cover fabric (used to provide better aesthetic appeal and soft handle) for the cover fabric to shift and move [9]. Therefore it can be concluded that the problem with the currently used products in the market can be characterized by either the lack of soft handle or/and the poor aesthetics properties of the spacer fabric [8]. Besides the importance of the texture surface to be used in cover fabric in which a soft texture proves and simulates a feeling of casualness and relaxation [10]. Low compression resistance and air circulation properties of the currently used piled fabric which are essential properties when the fabric is aimed to be used for seating application and especially in transportation where compression set is a priority of the fabric as mentioned in BS 3379-2005 [11], where the fabric is required to have a high compression set are not achieved by the conventional piled fabrics outlined and described at the start of this chapter.
So it can be attested that a need for a fabric that combine both of the characteristics of the piled fabric and spacer fabric is worthy of investigation to achieve a product that has high psychological comfort illustrated in soft texture surface of the fabric, as well as physiological comfort through the advantages of high air permeability and distinguished thermal conductivity of the spacer fabric, beside its high compression recovery properties contributing to enhanced tactile comfort of the product.

Materials

Spacer fabric
Warp knitted spacer fabrics were supplied by Heathcoat Fabrics Company, For use in this Study, three different 'qualities' of warp knitted spacer fabrics with each sample having different thickness and weight. In case of the blue coded fabric; a different surface structure and different surface whereas black and W+B coded samples each had the same surface structure as shown in table 1 below.

Table 1 Details of the sapcer fabrics used in the expirement

Spacer Fabric	Fabric Code	Thickness (mm)	Weight GSM	Spacer Yarn	Gauge (mm)	Surface Layer Structure
BLUE	N-02718-A01	3.75	330	Polyester Monofilament	3.5	Hexagonal mesh
Black	N-02589-A01	6	680	Polyester Monofilament	5.5	Rhombic mesh
W+B	N-01265-A01	6.45	780	Polyester Monofilament	6.25	Rhombic mesh

The spacer fabric thickness were not provided by the company, therefore the thickness was measured by using "Shirley Thickness Gauge" based on British Standards BS ISO 5084: 1997.

Tencel Carded web
The nonwoven carded webs used in this project were prepared in the NIRI laboratory in the University of Leeds. The Tencel Fibers had a diameter of 1.7 dtex ~40mm. These fibers were first carded, then pre-needled using the BYWATER needle punching machine. The needles used in this experiment had a length of 6.5cm and penetrated through the web into a depth of 1cm as shown in figure (1)

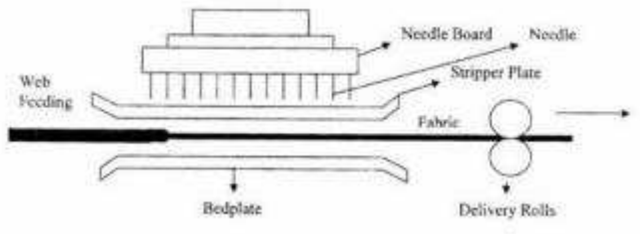

Figure 1 Schematic diagram of needle punching machine [13]

As compression and recovery were considered important characteristics of the fabrics under review it was decided that two different webs should be tested. And based on a research done by (Mao et al. 2007); Web i) had a weight of 100g/m2 and web ii) had a weight of 50 g/m2 [12]

Sample Preparation

As mentioned before, two different methods were used to generate the composite fabric
First, The composite fabric were prepared in NIRI Laboratory, where the warp knitted spacer fabric and the pre-needled Tencel web were both Hydro entangled together through the usage *of Hydro Spun Lace 3000 machine*.
The nonwoven Tencel web were positioned on the surface layer of the warp knitted spacer fabric before the Hydroentaglement. The composite fabrics were processed through the Machine at speed of 5 m/min. Where the surface layer of each sample was facing the water jet strips and the back layer of the composite was in reverse direction of the water jet strips and in contact with the conveyor belt of the machine.
Three sets of manifolds were used to achieve the integration of the nonwoven web with the spacer fabric;

1. First manifold was set at a pressure of 25 bar was responsible for pre-wetting the fibers.
2. Then the second and third manifolds used water air pressure of 135 bar to achieve the entanglement of fibers from the web through the spacer fabric.

Figure (2) shows explanation of the hydroentaglement machine [13].

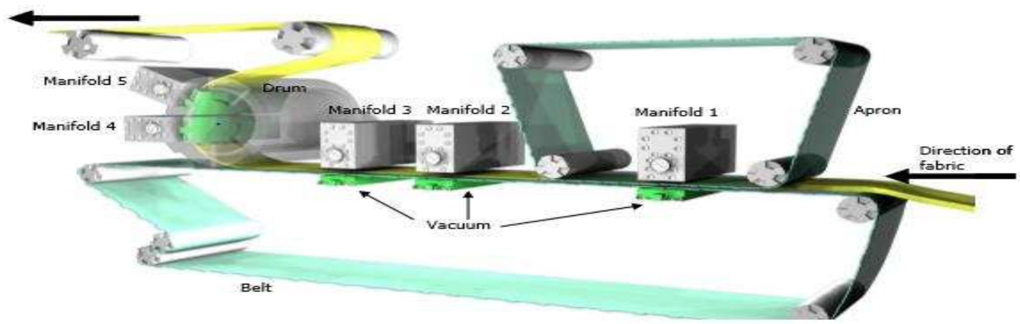

Figure 2 schematic of a lab scale hydroentangling unit [13]

The resultant composite fabric was taken to the drying drum to be initially dried in temperature of 90 c for 5 minutes, then the composite were put in oven for 45 minutes at temperature of 70c degree, where the temperature were selected just below the glass transition point of the polyester yarn used in the warp knitted spacer fabric [14] in order to avoid any potential damage while drying. Then the composite were conditioned for 24 hours at room temperature before starting the next phase of the testing in order to validate the experiment.

For the purpose of the study 6 different kinds of the composite fabrics were generated to be compared, where the three different kinds of the warp knitted spacer fabric were each hydroentangled separately with the two different nonwoven webs as Illustrated below in table (2).

Second, the other method used in generating the composite fabric where achieved through the usage of *BYWATER needle punching machine* instead of the Spun lace, as the nonwoven Tencel web were positioned on surface layer of the warp knitted spacer fabric. Then both the spacer fabric and the nonwoven Tencel web positioned on top of the spacer fabric went through the needle punch machine. Needles penetrate from the surface layer of the spacer fabric and went through the back surface layers, allowing the fibers of the nonwoven Tencel web positioned on the surface layer to penetrate into the structure of the spacer fabric and interlock within the two surfaces of the spacer fabric.

The spacer fabric used in this process coded as Blue, the nonwoven Tencel web used have a weight of 100 GSM, and the resultant composite fabric is coded as NP Blue 100 as shown in Table (2)

Table 2 Properties of the composite fabric samples produced

Spacer fabric	Spacer Fabric's weight (g/m2)	Nonwoven web's weight (g/m2)	Composite Weight	Thickness (mm)
Blue 50	330	50	380	4.3
Blue 100	330	100	430	4.4
NP Blue 100	330	100	430	5.3
Black 50	680	50	730	6.1
Black 100	680	100	780	6.3
B+W 50	780	50	830	6.7
B+W 100	780	100	880	7.1

Testing procedure

In order to fully examine if there were any identifiable differences had occurred between the functions and performance properties of the initial three warp knitted spacer fabric and the 6 generated composite fabrics identified above in table (1), where integration and changes over the structure of the warp knitted spacer fabrics were made, a series of test carried out as follows:

1. Thermal Resistance.
2. Compression resistance.
3. Compression set.
4. Air permeability
5. Abrasion resistance
6. Water vapor permeability

Determination of Thermal Resistance and Thermal Conductivity

Thermal comfort of the generated composite is considered as a main propertiy that the composite should be capable to deliever, as a high level of thermal conductivity and low thermal resistance contribute to a better psychological comfort as the generated product is designed to be in direct contact with the user and for a long term of time.

Therefore *Tog Meter test* was used to determine the thermal resistance of textile fabrics, where the test is taken in steady state conditions with less effect and less consideration of ability of the wind effects through the fabric. Resulting in values that indicate the fabric resistance to heat loss [15].

Tog value is defined as 1/10 difference in the temperature across the two surface of the tested fabric, as a result of the heat flow in watt per square meter

Determination of Compression Resistance

One of the most significant factors that determine the tactile comfort of the fabric, is its compression resistance, especially when the fabric is used for cushion application; a high compression resistance leads to better comfort and more satisfaction. And in the case of this research; the compressional resistance properties of the developed fabric are important parameters and significant performance characteristics of the fabric. The developed fabric is intended to be utilize for serving dual function illustrated in a cover fabric for upholstery and as a replacement for the cushioning materials beneath the cover fabrics. Therefore the changes and developments carried over the structure of the initial warp knitted spacer fabric need to be investigated.

In order to fully examine the compression resistance of the generated composite fabric, the effect of the carded web being integrated to the spacer fabric, and what effect it has over the compression behavior of the initial warp knitted spacer fabric, the compression resistance test via “Instron testing machine” was utilized [16].

Determination of Compression Set

The compression set defined as mention in the British Standards BS ISO 1856:2000, as the difference in fabric’s initial thickness and its thickness after being compressed for pre-determined time, were this parameter is used to identify the compression recovery level of the fabric, as the fabric thickness is measured before and after applying the weight needed to obtain the deformation required.

After testing the samples’ compression resistance. The force required to deform the fabric were determined, And based on BS ISO 1856:2000 [17], the fabric were examined based on Method B of testing (Compression at standard conditioning Temperature). After selecting the Different weights required to achieve 75% displacement in samples based on the test results, samples were put under those weights. Initial thickness of the samples were measured based on BS ISO 5084: 1997, compressed under those weights for 72 hours. Samples were left to recover for (30 ± 5) min followed by measurement of the thickness to determine compression recovery characteristics.

And based on the equation given below, the compression set values of tested samples were determined

$$C.S. = (d0-d1/d0) \times 100$$

Were: “d0” is the initial thickness of the fabric. And “d1” is the thickness of the test piece after recovery.

The tested fabric is required to meet certain requirements and specification that are classified based on the purpose of its end use as mentioned in BS ISO 3379: 2005 [11] and explained in the Table 3 below.

Table 3 Classification of fabric based on the purpose of its end use

Class	Type of Service	Recommended application	Compression set (maximum) %
X	Extremely severe	Heavy duty contract seats Heavy duty public transport seats	8
V	Very severe	Public transport seats Cinema and theatre seats Contract furniture seats	8
S	Severe	Private and commercial vehicle seats Domestic furniture seats Public transport backs and armrests Cinema and theatre backs and armrests Contract furniture backs and armrests Domestic foam mattress cores	12
A	Average	Private vehicle backs and armrests Domestic furniture backs and armrests Component layers for domestic mattresses (excluding cores)	15
L	Light	Padding and Scatter cushions	15

Determination of Air Permeability

The air permeability properties of the fabric are a very important factor influencing the comfort characteristics. Where fabrics are considered to be more comfortable and desired when having a higher value of air permeability, and high air circulation within the fabric which allow more air to move within the structure, and less air to be trapped which cause discomfort feeling and increase thermal insulation. And while warp knitted spacer fabric is known for the high air permeability, significant change over this feature was anticipated to result when incorporated with the Tencel nonwoven carded web. As the fabric is required to maintain high level of air permeability, Air permeability test was conducted to compare this features of the initial warp knitted spacer fabric against the generated composite fabrics, and the equipment used is" Air permeability tester FX3300". Tests were performed based on the British Standards BS 5636 [18].

Determination of Abrasion Resistance

Abrasion resistance of any fabric used for as cover fabric that is designed to be in contact with the end user body; is required to have a good level of abrasion resistance to sustain and last longer. And in this project; abrasion resistance of the developed composite fabrics is considered one of the main features and important performance requirement. As it is used in several application including cover fabric for car seats, bus and transportation seating fabric, abrasion force is continuously exerted over the surface layer. Therefore special performance characteristics of the fabric are required to fulfill the expected performance properties and to achieve the durability required to meet these applications, which is defined as the ability of the fabric to withstand deterioration or wearing, including the effect of abrasion [19].

Determination of Water Vapor Permeability

Fabric with high permeability to water vapor, means better and higher psychological comfort and more satisfaction, in contrast; low level of water vapor permeability leads to less satisfaction and low thermal comfort as less water vapor molecules pass from one surface of the fabric to the other, which leads to accumulation of those water vapor molecules that are responsible for the sticky and wet feeling when body is in contact with fabric surface for a long time, therefore a high water vapor permeability is required and desirable characteristic of fabrics designed to be in contact with human body.

Therefore; and based on Based on ISO 11092; 2014 [20], sweating guarded hot plate was used to examine the water vapor permeability of the generated composite fabrics. This testing method simulates the transformation of moisture generated from the human body through the fabric and give indicator of the thermal comfort properties of the developed fabric. The test is taken under steady state conditions [21].

Results and Discussion

Thermal resistance

Results of the fabric's thermal resistance and thermal conductivity are shown below in Table 4, Figures 3 and 4 show difference in performance between the different tested samples as shown below:

Table 3 Thermal resistance and thermal conductivity of the resultant fabrics

Fabric type	thickness (mm)	tog	thermal resistance (m^2KW^{-1})	thermal conductivity K-value (W m^{-1} K^{-1})
B+W	6.450	1.221	0.122	0.0528
B+W 50	6.700	1.310	0.131	0.0511
B+W 100	7.100	1.317	0.132	0.0539
Black	6.000	1.250	0.125	0.0480
Black 50	6.100	1.265	0.127	0.0482
Black 100	6.300	1.270	0.127	0.0496
Blue	3.750	1.320	0.132	0.0284
Blue 50	4.300	1.340	0.140	0.0307
Blue 100	4.400	1.370	0.137	0.0321
NP Blue 100	5.300	1.450	0.145	0.0365

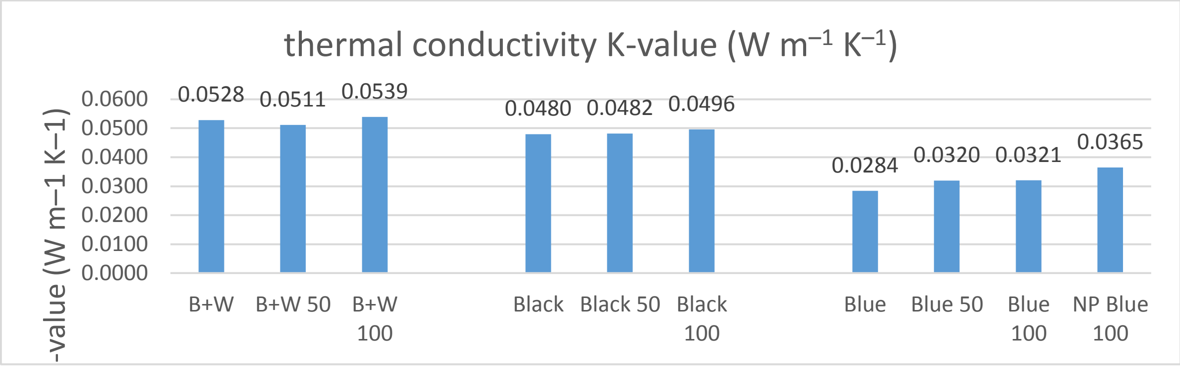

Figure 3 thermal conductivity of the of the resultant fabrics

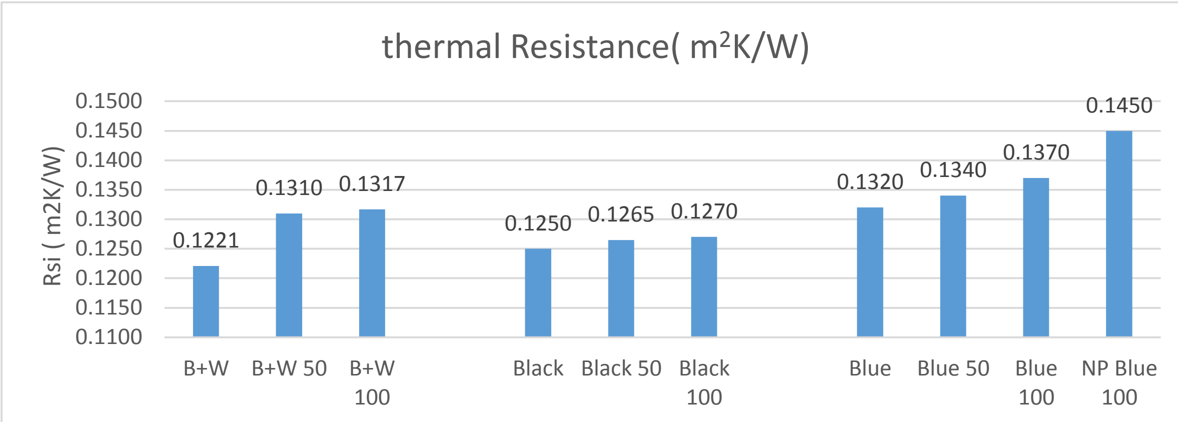

Figure 4 comparison between the thermal resistances of the resultant fabrics

Results from the Table 4 show that thermal conductivity and the fabric thickness have positive linear relationship, where the fabric with higher thickness; shows higher value of tog value. And Figure 4 shows the thermal resistance of the composite fabric increased when the nonwoven Tencel web were added to the warp knitted spacer fabric. Nevertheless, the Needle punched composite, coded as NP Blue 100, showed higher thermal resistance when compared to the same kind of initial warp knitted spacer fabric coded as Blue.

Besides, the surface structure significantly contributes to the thermal resistance of the initial Spacer fabrics. Blue coded fabrics have Hexagonal Mesh surface structure, while samples B+W and Black which have more open mesh and Rhombic surface structure allowing more fibers to be interlocked and integrated within the structure, which in turn leads to more air trap between the two sample's surface and increase the thermal resistance of the composite. Furthermore; the Tencel web itself contributed to different levels of thermal conductivity, as it could be seen in sample B+W50, where the Tencel web lead to less conductivity even when the thickness where increased.

Compression strength

Samples were compressed till the thickness of the specimen were reduced by more than 75% of its initial thickness in order to record and get the stress-strain curve and figure out the required for to cause a deformation of 75% less thickness in the specimen.

Figure (5) illustrates the difference of force required to compress the samples and the amount of thickness that is needed to be reduced in order to get the required deformation.

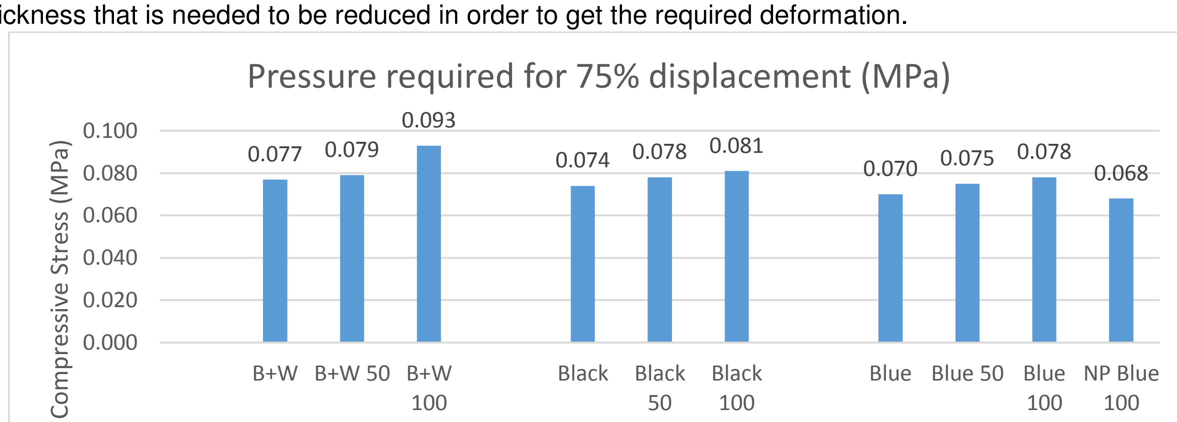

Figure 5 forces required to cause displacement in fabric thickness by 75%

As shown in figure (5), the force required to compress the B+W is higher than the force required to compress both the Black and the Blue coded spacer fabrics. Beside it could be notice from the chart that fabrics generated through hydroentanglement integration process, required higher compressional force to obtain displacement compared to the initial warp knitted spacer fabrics. And that the compression force needed in to compress B+W100, Black 100, and Blue100, is 17.7%, 3.8% and 4% respectively higher than the force required to those in B+W50, Black50, and blue50 to trigger a deformation of 75%. While less compressional force is required to compress the needle punched spacer fabric integrated with 100GSM Tencel web (NP Blue 100), compared to both the initial blue coded spacer fabric and the Blue 100, as compression force is 2.85% and 12.8% lower compared to Blue and Blue 100 respectively.

Compression Set

Samples were compressed by pressure causing a displacement of 75% in the thickness for 72 hours, results were obtained and shown in table 5 below.

Table 4 Compression set 75% values of the resultant fabrics

Fabric type	initial thickness (mm)	Thickness after 30 min of releasing (mm)	Pressure required for 75% deformation (MPa)	compression set C.S %
B+W	6.45	6.10	0.077	5.43
B+W 50	6.70	6.30	0.079	5.97
B+W 100	7.10	6.60	0.093	7.04
Black	6.00	5.60	0.074	6.67
Black 50	6.10	5.65	0.078	7.38
Black 100	6.30	5.55	0.081	11.90
Blue	3.75	3.50	0.070	6.67
Blue 50	4.30	4.00	0.075	6.98
Blue 100	4.40	4.10	0.078	6.82
NP Blue 100	5.30	4.10	0.068	22.64

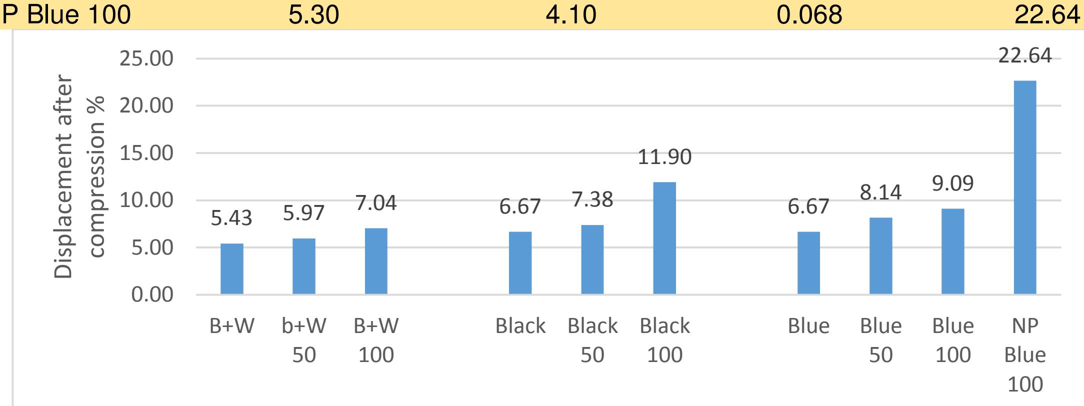

Figure 6 Compression set values after applying pressure for 72 hours

Figure (6) demonstrate both the changes in compression set values, and the percentage of deformation occurred after compressing the fabric. It was clear that the recovery properties of the regenerated fabrics were reduced when compared to the values of the initial warp knitted spacer fabrics. . Beside a noticeable reduction were also recorded for all generated fabric, were recovery properties where less in the composite fabric integrated with the 100 GSM Nonwoven Tencel web, compared to those hydroentegrated integrated with 50 GSM nonwoven Tencel webs. As a reduction of 1.61%, 5.23% and 2.42% for fabrics B+W100, Black 100 and Blue 100.

Even more, the most remarkable reduction in compressional recovery properties where observed in sample NP Blue 100, where after increasing the thickness by 41.3% compared to the initial Blue coded spacer fabric, compressional recovery where reduced by 15.97%.
To sum up, several factors contribute to the different level of compression recovery, as first the increment in samples' thickness lead to higher compression recovery. Secondly; the surface structure of the initial spacer fabric affected the compression behavior, as Blue coded samples that have a different surface structure and porosity; a lower compression recovery compared to the identical B+W and Black coded samples that are different in thickness only. Finally the technique used in integrating the nonwoven web to spacer fabric changed the compression behavior, as results shows that hydro integrated composite have higher compression recovery than needle-punched sample made from same materials, and this is explained due to the damages resulted when the needles of the needle punch machine penetrated to the spacer fabric and damage and cut the spacer yarn which is responsible for the compression recovery behavior of the spacer fabric, which could be reduced through the usage of more closed surface structure and less inclined spacer yarn [400].

Abrasion resistance

Based on results shown in figure (7); two different behavior of samples' resistance to abrasion were observed; differ base on the kind of the initial warp knitted spacer fabric used and the method used to mechanically integrate the nonwoven Tencel web into the spacer fabric's surface. B+W and Black coded spacer fabrics which have a similar fabric structure with difference in thickness only, showed that the higher weight of the nonwoven Tencel web integrated into their surface lead to lower resistance against abrasion. Beside their narrow surface mesh lead to less fibers to be integrated into the structure when higher weight of web were added to the initial fabric.

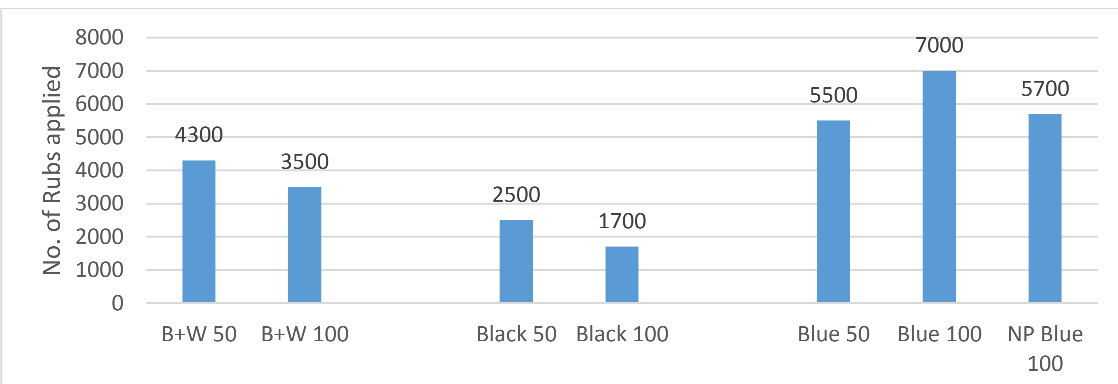

Figure 7 Abrasion resistance ------- no. of rubs causing surface nonwoven fabrics to breakdown

Figure 7 shows difference in no. rubs causing samples to breakdown. While Blue coded samples which have more open surface mesh compared to Black and B+W samples, and the Hexagonal structure all contribute to more penetration of the web's fibers into the spacer fabric structure resulting in more interlocking and higher integrity. And a higher abrasion resistance where achieved when higher amount of Tencel web hydro integrated to the surface structure.

Air permeability

A reduction in air permeability were observed as shown in figure (8) after the integration of the nonwnoven Tencel web to the initial warp knitted spacer fabrics, due to the higher amount of air trapped between the two surface of the initial spacer fabric after integrating the initial samples with the nonowoven web, where the initial spacer fabrics B+W, Black and Blue showed a reduction in air permeability values of 28%, 20% and 53% after integrating the 50 GSM Tencel web, and 26%, 1.2%. 22% reduction of air permeability of spacer fabric integrated with 100 GSM nonwoven Tencel web compared to samples integrated with 50 GSM nonwoven Tencel web.

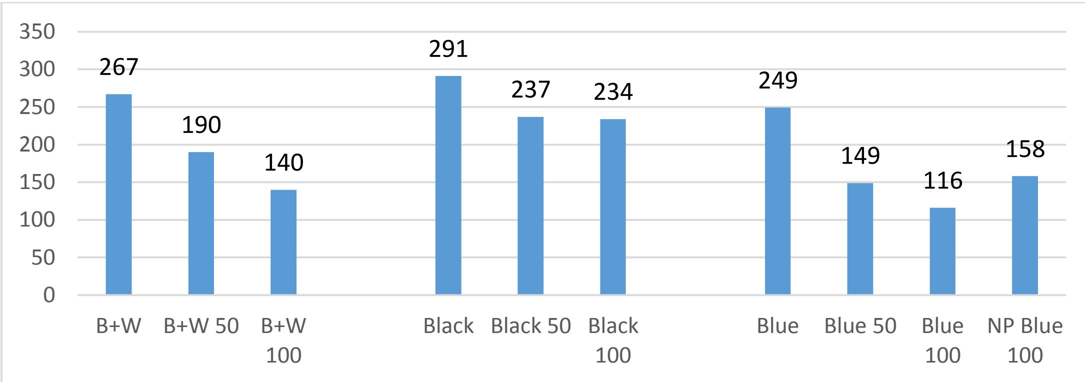

Figure 8 Air permeability ($cm^3/cm^2/s$) of the resultant fabrics

And the more open surface structure of the Blue coded fabric; allowed more fiber to be integrated within the structure leading to more air to be trapped in between and less air permeability of the fabric after adding the nonwoven Tencel web into the surface.
Furthermore, the reduction were also affected by the technique used to integrate the web, as two samples of the same initial spacer fabric and same weight of the nonwoven Tencel web integrated to their surface; shows different reduction in air permeability values, as sample coded Blue 100 showed a reduction of 53% compared to sample coded (Blue), while sample NP Blue 100 reflected a reduction of only 36% compared to sample coded Blue.

Water vapor resistance (Ret)

Results from Figure 9 show that the higher the weight of the nonwoven Tencel web, led to increment in the water vapor resistance of the generated samples, as samples coded (B+W100, Black 100 and Blue100) showed increment of 4.99%, 5.38% and 4.5% when compared to the same hydroentangled samples coded as B+W50, Black50 and Blue 50. As results shows that increasing the thickness and the weight of the nonwoven Tencel web both effected the water vapor permeability, where a negative relation between both fabric's thickness and water vapor resistance were found, as water vapor molecules will required more space to pass from one side to another, especially in the case of NP Blue 100, were and compared to sample Blue consisting of the same materials, with 20.45% increment in thickness, water vapor permeability were reduced by 42%.

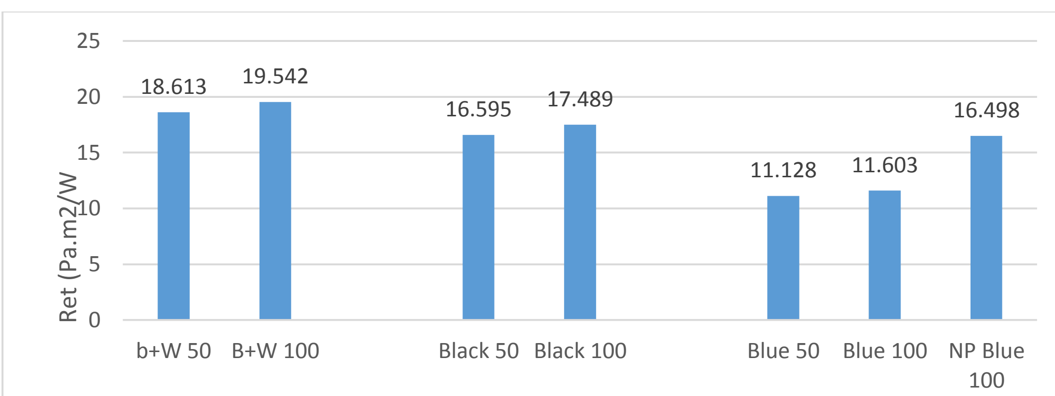

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Figure 9 water vapour resistance of the resultant fabrics

Conclusions

This research aimed to developed and improve the aesthetics appeals and tactile comfort of the warp knitted spacer fabric without overly compromising its initial unique characteristics and performance properties, therefore after preparing the samples; a serious of examination were conducted to test the difference and changes occurred.

After comparing the thermal resistance and thermal conductivity of the developed composite against each other and similar composite developed in different literature [205], it was found that samples developed in this research meet the requirement and have a better thermal comfort properties when compared to similar products.

The compression recovery properties of the developed composite are important parameter when evaluation the performance of those samples due to their minor requirement illustrated in serving as cushioning materials. Therefore samples' compressional recovery were measured and compared against the British Standers BS 3379:2005 [11], and results showed that all samples met the requirements set by the British Standers with the exception of sample coded NP Blue 100, were severe damage over the spacer yarn responsible for the compression resistance properties of the spacer fabric occurred when needles penetrated through the fabric's structure. Nevertheless, the usage of more close mesh structure and less inclined spacer yarn will result in less damage over the spacer yarn.

Furthermore the Air permeability and air circulation properties of the developed composite are essential requirements properties as they contribute to better comfort and less air trapped between the human body and the textile surface, therefore these features were investigated, measured and then compared to another seat cover fabric mention in patent CA 2488545 A1 [22], and based on the patent the desired level of air permeability were achieved and met by all the samples produced.

While abrasion resistance is significant factors when assessing the durability of the textile materials that are directly in contact with the human, and especially in the case of this research as the research aims to provide textile fabric suitable for seats and domestics upholstery; this property of the developed fabric failed to meet the requirements of the British Standards BS 14465:2003 [23], and further work were suggested in different chapter to improve the composite durability against abrasion and pilling.

Examinations over the water vapor permeability properties of the developed composite were conducted. As this features attribute to high psychological and thermal comfort properties as higher permeability contribute to the reduction of the sticky feeling between the human body and contacted textiles as less water vapor molecules accumulate, providing dry and suitable surface for long term usage. And based on the results and comparison against similar available product in the market as mentioned earlier and information obtained from Patent US 20140346820 A1 [25], and a study done by (Volkmar, 2003); All of the developed composites successfully met and enhanced the properties and characteristics required for the intended application.

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