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Evaluation of the Mechanical and Functional Properties of Velvet Fabrics Treated with Fluorocarbon

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VELVET fabrics are a type of pile weave structure, representing a significant percentage of the total upholstery fabric consumption. It is not only famous upholstery fabric but also is gaining importance in other textile end uses. The main idea of this research, depending on producing two warp pile fabrics with two different structures (1/2V & 3/6 W) which used in upholstered furniture application and treated with fluorocarbon finishing agent to improve its properties to meet the functional purpose it is produced for. The results show that the warp pile structure and finishing treatment have significantly affected the mechanical and functional properties of produced fabrics, as tensile strength, air permeability, abrasion resistance, contact angle and water repellent. Addition to the results showed that the functional properties were durable even after 10 laundering cycles.

Keywords: Velvet fabrics, Face to Face, Pile fabrics, Upholstery, Contact angle**,** Functional properties.

Introduction

Pile fabrics are one of the finest textiles, which is characterized by the appearance of lavish and comfortable soft surface of the fingers and eyes[1]. Velvet fabrics are classified as pile fabrics which are divided into two types according to the pile direction: weft pile fabrics known as velveteen and warp pile fabrics, also known as velvet [2,3]. Velvet fabrics may be found in a variety of applications such as jewelry boxes, bathroom carpets, curtains, upholstery, automotive interiors, prayer mats and wall rugs. Long pile velvet is used to imitate fur and technical fabrics[4]. The two largest markets for these fabrics are automotive industries and home furnishings.

Velvet fabrics are manufacturing with two weaving methods; wire weaving technique and face to face (double pile fabric) weaving technique [3]. Face-to-face weaving represents an alternative method of manufacture of the cut warp pile fabrics in which two cloths are woven simultaneously. Two separate ground fabrics with a space between them, each with its own warp and weft, are woven on the unstitched double-cloth principle, while the pile warp threads interlace alternately with the picks of both fabrics [5].

Velvet fabrics produced by face to face method need two sets of warp threads (one for the pile and the other for the ground) and one set for weft [1] as shown in Figure (1).

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The main function of the ground yarn is to support the structure and create a base which meets tensile and seam fatigue requirements. However, any stretch requirements would be a function of ground yarn and structure and would have to be approached in the way described for flat woven although there would be much less opportunity to influence yarn crimp. The pile yarn is the main feature and must meet aesthetic design, color and the main technical requirements such as tuft adhesion, abrasion and lightfastness [7].

The weave structure of velvet fabrics consists of two weaves, one for the pile and the other for the ground. The common weaves for the ground are plain 1/1 and warp rib 2/1 or 2/2 [8]. There are many different weave structures associated with velvet particularly in relation to the interlacing of the pile yarns and often velvets are referred to as 'V', 'U', or 'W' weave [10]. As shown in Figure (2).

Water/oil proof finishing for clothes or technical textile or Velvet fabric is considered one of major textiles industry. Proofing or repellency finish becomes more and more common in products used at home, as well as for the outside [2,9,10].

Water/oil repellent is more remarkable characteristic for some velvet fabrics, the fluorocarbon agents is the most effective treating agent for this property. The most fluorocarbon agents have low durability to washing. This decrease of washing is thought to be mostly due to the rotation of reactive groups into fibers to repel the hydrophobic washing conditions. Many researches used crosslinking agent with fluorocarbon to improve the durability of washing for natural fibers [10-12].

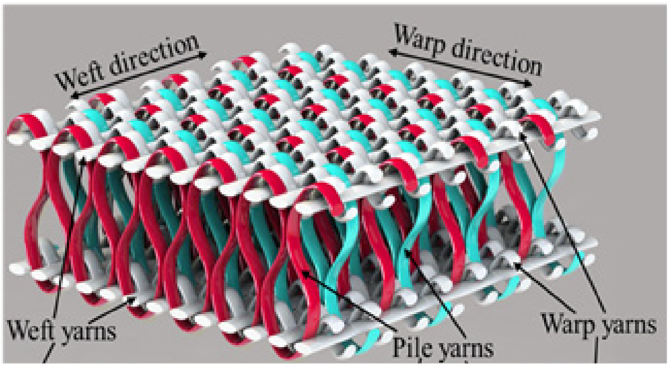


Fig. 1. Velvet Fabric Construction[6].

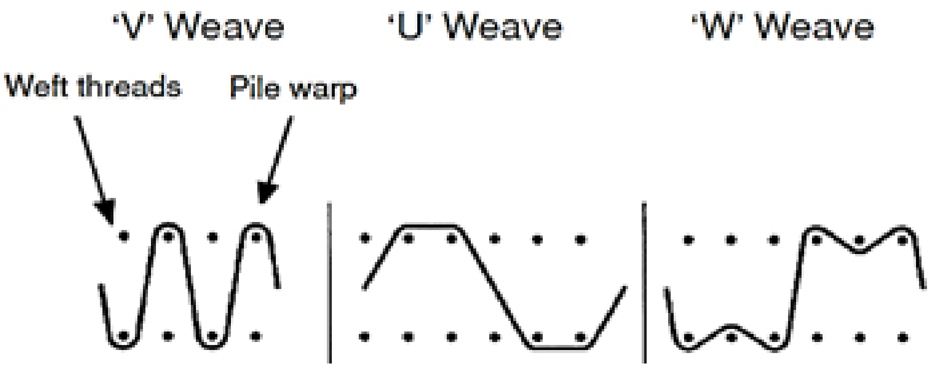


Fig. 2. The Basic Shape of Pile Tufts [7].

In spite of required of functional properties like Water/oil repellent, the fastness properties of functionalized textile toward wash is a major challenge [13].

The stain resistance has been a much-desired property in home textiles, which are in constant contact with greasy and moist surfaces [14]. For a textile to be stain resistant, it needs to be both water and oil repellent [15]. The basic objective of stain resistance can be achieved by utilizing the inherent properties of certain fibers or by applying coatings, finishes to fabric surfaces.

If the adhesive interactions between a fiber and a splash of liquid placed on the fiber are greater than the internal cohesive interactions within the liquid, the splash will spread as seen in Figure (3). The splash of liquid will not spread when the adhesive interactions between the fiber and the liquid are less than the internal cohesive interactions within the liquid, and the contact angle between the surface and the liquid exceeds 90 degrees [15].

In the present work Firstly, we attempt to produced two pile fabrics in different conditions and parameters, secondly treated this fabric with fluorocarbon compound using pad dry cure process. The fabrics was evaluated before and after treatment for oil and water repellent, contact angle analysis, addition to some of physical and mechanical properties to determine the effect of geometrical construction and finishing treatment of produced fabrics on the functional properties.

Experimental Work

Materials

Specification of Produced Fabrics

In this study two face to face (double warp pile) dyed fabrics with disperse dyeSuncron® Grey SE-GMS and Suncron® Brown S-AF, OHYOUNG INDUSTRIAL CO., LTD.

Which used for upholstered furniture applications were produced by using two different pile structures (1/2V, 3/6W) as shown in Figures (4 & 5).

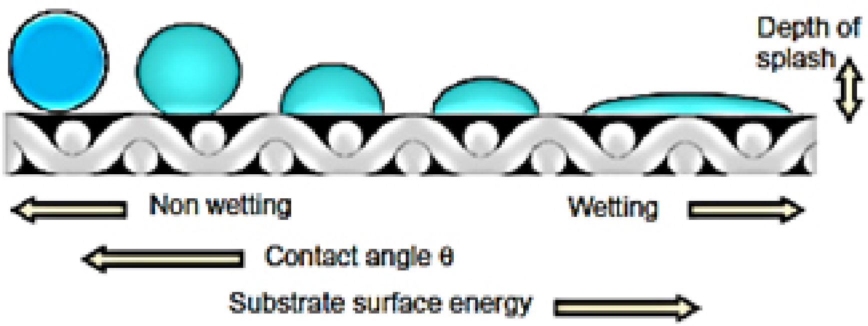


Fig. 3. Relationship between Surface Energy and the Liquid Contact Angle [15].

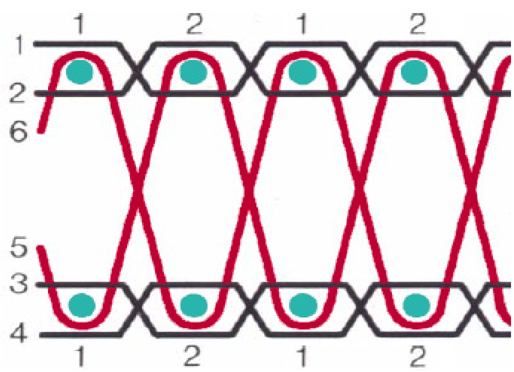


Fig. 4. Cross Section for Sample (1) –1/2 V.

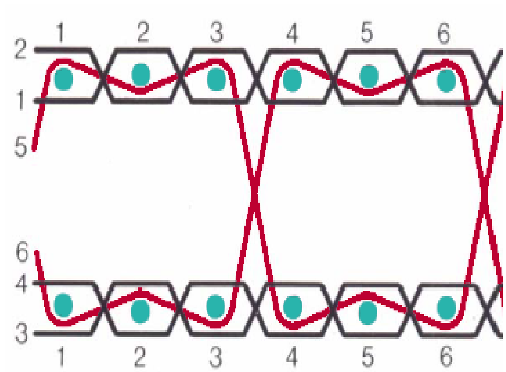


Fig. 5. Cross Section for Sample (2) –3/6 W.

The research samples were produced at Texmar Company for upholstery fabrics, using adob by machine with the specifications shown in Table (1). The below Table (2) show that the operational specifications of the produced samples.

The fabric was not subjected to any type of finishing treatments. The fabric was further washed with a solution containing 5g / L sodium carbonate and 5g / Lnon–ionic detergents at boil for 30 min. It was then rinsed with hot and cold water and left to dry in air at room temperature.

Specification of Finishing Materials

The finishing agent used was GBstain Repellent® FC(fluorocarbon compound; BASF), and Hostapal® CVL-ET (nonionic wetting agent based on alkylarylpolyglycol ether, Clariant).

TABLE 1. Specifications of the Loom Used in Producing Research Samples.

NO.	Property	Specification
1	Machine Manufacturer	GÜSKEN
2	Type of machine	Face-to-Face, Double Rapier
3	Shedding System	dobby
4	Dobby Type	Stäubli
5	Number of dents per cm	6 dents/cm
6	Denting System	6 ends/ dent (2pile + 4 ground)

TABLE 2. The Operational Specifications of the Produced Samples.

No.	Property	Specification of Sample (1)	Specification of Sample (2)
1	Pile warp material (dyed)	polyester	polyester
2	Pile warp yarn count	300D/288F *	300D/288F
3	ground warp material	polyester	polyester
4	ground warp yarn count	300 denier (Intermingle)	300 denier (Intermingle)
5	No. of pile warp ends	20/cm	20/cm
6	No. of ground warp ends	20/cm	20/cm
7	Ratio between pile and ground yarn	**2** Pile: **2** ground	**1** Pile: **1** ground
8	No. of picks per cm	20 picks/cm	20 picks/cm
9	Weft yarn material (dyed)	Polyester, spun	Polyester, spun
10	Weft yarn count	30/2 Ne	30/2 Ne
11	Pile weave structure	1/2 V	3/6 W
12	Ground weave structure	Plain 1/1	Plain 1/1
13	Pile height	2mm	2mm
14	Pile density / cm^2	200 tufts / cm^2	66 tufts / cm^2

***D**: refer to denier count system, whilst **F**: refer to filaments (Number of fibers / yarn cross section)

Fabric Finishing Treatment

The aqueous finishing bath was prepared by mixing the active finishing agent (150 g/L), and the nonionic wetting agent, the pH of the finishing liquor should be adjusted to 5.0. The fabrics were padded twice with 100 % wet pick-up by freshly prepared aqueous finishing solutions. Padded fabric samples were followed by drying at 100◦C/5 min, and cured at 170 ◦C/45 sec. The cured fabrics were then rinsed with distilled water at 50 ◦C for 30 min and rinsed and finally dried at ambient conditions[16-19].

Laboratory Tests Applied to Samples under Study

Laboratory tests of produced and treated samples were carried out to check the functional properties that suit its use as upholstery fabrics.

Abrasion Resistance Test (Mass Loss)

This test was carried out by using (Martindale Abrasion Tester) according to the American Standard Specification of (ASTM D4966 –12–2016).

Tensile Strength and Elongation Test (Strip Method)

This test was carried out by using *(*SDL ATLAS tester*)* according to the American Standard Specification of (ASTM D5035-11-2015).

Air Permeability Test

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

Color Strength Test (K/S)

This test was carried out the obtained treatments dyed fabrics, expressed as K/S values, was calculated from reflectance data using Kubelka-Munk equation [20, 21].

$$K/S = (1-R)^2/2R$$

where K and S are the absorption and scattering coefficient respectively, and R is the reflectance at wavelength of maximum absorbance of the used pigment colorants.

UV-Protection Factor (UPF)

This test was calculated according to the Australian/New Zealand standard.

Water & Oil Repellence Test

Water repellency (WRR) and oil repellency rating (ORR) were performed using the spray test method AATCC (22-2014)[22], and AATCC test method (118-2013).

Contact Angle Test

Contact angles were measured with 8 µl deionized water droplet on a Dataphysics OCA 15EC (Dataphysics, Germany) instrument at room temperature. The contact angle between fabric and water drop was calculated by means of Young's equation.

Fastness Properties Test

Fastness properties to washing, rubbing and light were evaluated according to AATCC test methods: (61-2013), (8-2016), and (16A-2004) respectively.

Durability to Laundering Test

This test was calculated according to AATCC Monograph Standardization of Home Laundry Test Conditions AATCC (M6-2016).

Result and Discussion

Results of the experimental tests carried out on samples under study are presented in the following tables and graphs. Results were also statistically analysed for data listed and relationships between variables were obtained.

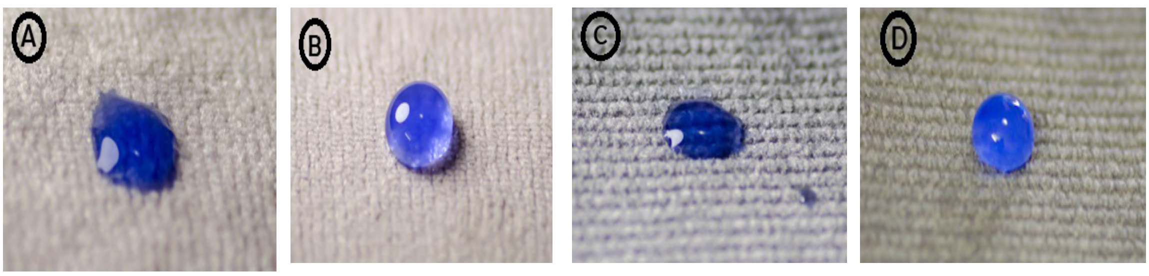


Fig. 6. contact between colored water drops and fabric surface (A) untreated sample 1, (B) treated sample 1, (C) untreated sample 2 and (D) treated sample 2.

TABLE 3. Treated and Untreated Fabrics Testing Results.

S. No.	Treatment	Pile Weave Structure	Testing Results								
			Fabric weight	Thickness	Abrasion Resistance	Warp Tensile strength	Weft Tensile strength	Air perme ability	Water Repellence	Oil Repellence	Contact Angle
			g/m²	mm	%	N	N	L/m²/S	grade	grade	degree
1	without	1/2 V	490	1.36	1.62	408	399	82.6	20	3	71.5
2	without	3/6 W	320	0.74	0.94	339	530	104.5	20	3	88.5
3	treated	1/2 V	580	1.6	2.65	684	814	41.8	70	6	139
4	treated	3/6 W	407	0.93	2.1	533	1271	64.6	80	8	141.6

Fabric weight

Effect of pile structure on fabric weight is show in Figure (7) and Table (3), it clear the samples which produced with pile structure (1/2 V) have recorded the highest rates of weight, whereas samples made of Structure (3/6 W) have recorded the lowest rates of weight. This is mainly because of tufting formation where at pile structure (V) the pile tuft formed every two picks, whilst at pile structure (W) the pile formed every six picks, as shown in Figures (4 & 5). As a result, the structure with a smaller number of picks for one repeat, leads to an increase in pile density as shown in Table (2), so that the pile structure (V) gave more fabric weight than pile structure (W).

All samples were weighed before and after the treatment and the values were fitted to the below Equation to obtain weight gain percentage [23]:

$$\text{Weight gain \%} = [(\text{weight}_{\text{after treatment}} - \text{weight}_{\text{before treatment}} / \text{weight}_{\text{before treatment)}}] \times 100$$

Table (3) and Figure (8) shows that the sample with the pile structure (3/6 W) has recorded the highest rates of weight gain followed by the sample with the pile structure (1/2 V).

Also show that the sample with the pile structure (3/6 W), has recorded weight gain 27.2 % but sample with the pile structure (1/2 V) recorded weight gain 18.4 %, this result indicate that the structure of tufting formation of sample (3/6 W) absorption the finishing agent higher than (1/2 V) because the pile structure open in sample (3/6 W) than (1/2 V). that is mean the pile structure plays an important role in finishing treatment.

Fabric Thickness

Figure (9) and Table (3) shows that the produced sample with structure (1/2 V) had recorded the highest rates of thickness. This is due to the structure of (1/2 V) produced from 2 picks, whereas the structure of pile shape (3/6 W) produced from 6 picks, as shown in Figure (4 & 5). So, as a result the structure with lowest number of picks per unit gives the more pile density per unit area, which leads to increase the covering of the fabric surface, so that the fabric thickness increases.

The structures of tufting formation of samples are play as the main factor in treatemt condition with finishing agent. The sample pile structure (3/6 W) is adsorption and absorption the finishing agent higher than sample pile structure (1/2 V). The water absorption rateis is higher in samples (3/6 W) than sample (1/2 V). After treatment the pile type has significant influences on fabric thickness.

Fabric Abrasion Resistance

Effect of pile structure on abrasion resistance is show in Figure (10) and Table (3), it can be seen that structure (1/2 V) has scored high rates of weight loss followed by structure (3/6 W) after 20,000 cycle. This is because the pile structure (3/6 W) has a high tuft adhesion since it is anchored by three wefts [7].

The fabric construction is the main factor in the treatment in sample (3/6 W) is roughness than sample (1/2 V). the rate of weight loss in treated sample (1/2 V) about 3 % but in treated sample (3/6 W) about between 2-2.5 % higher than both untreated because the finishing agent coating the surface area of fabrics make roughness of treated samples better but abrasion resistance is lower in treated samples than untreated.

Tensile Strength in Warp Direction

Figure (11) shows that the pile structure 1/2V

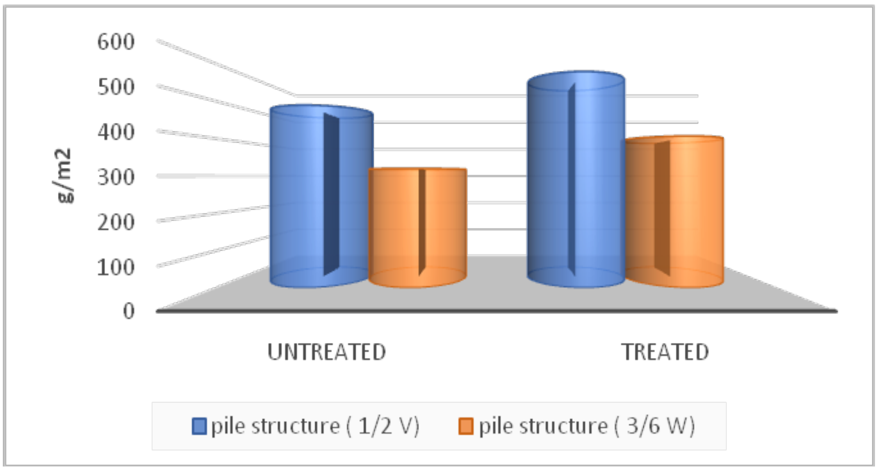


Fig. 7. Relationship between pile structure and fabric weight.

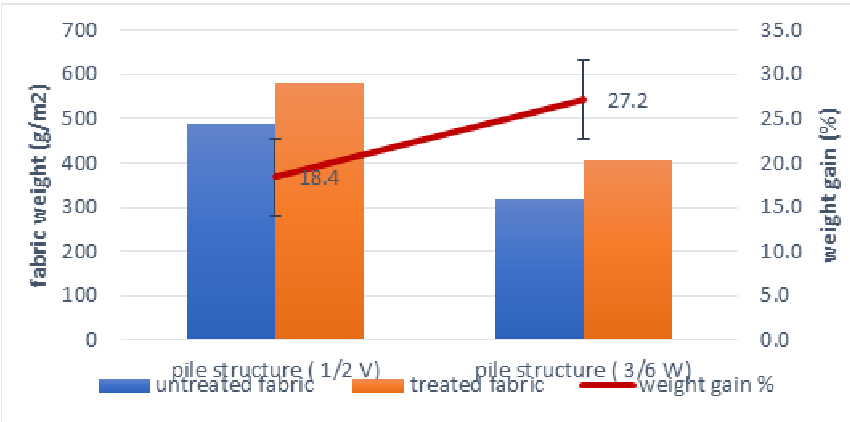


Fig. 8. Relationship between pile structure and the weight gain percentage.

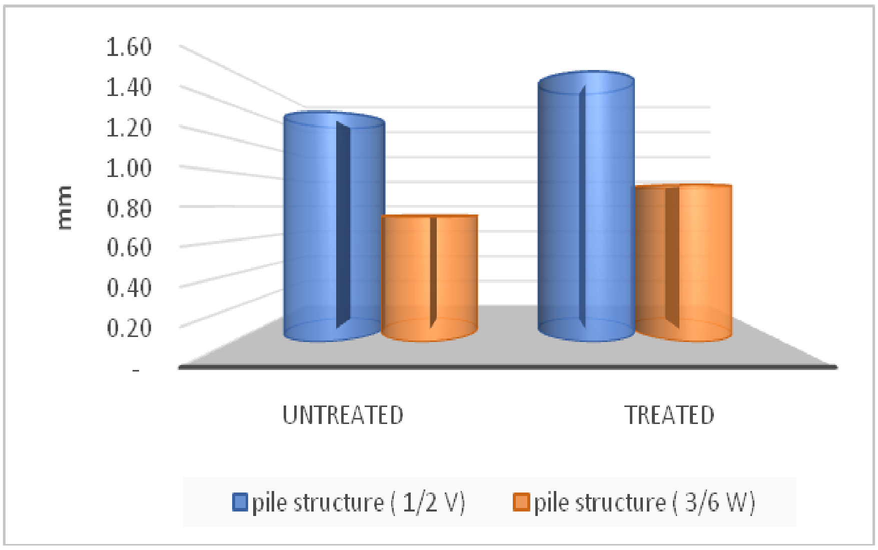


Fig. 9. Relationship between pile structure and fabric thickness.

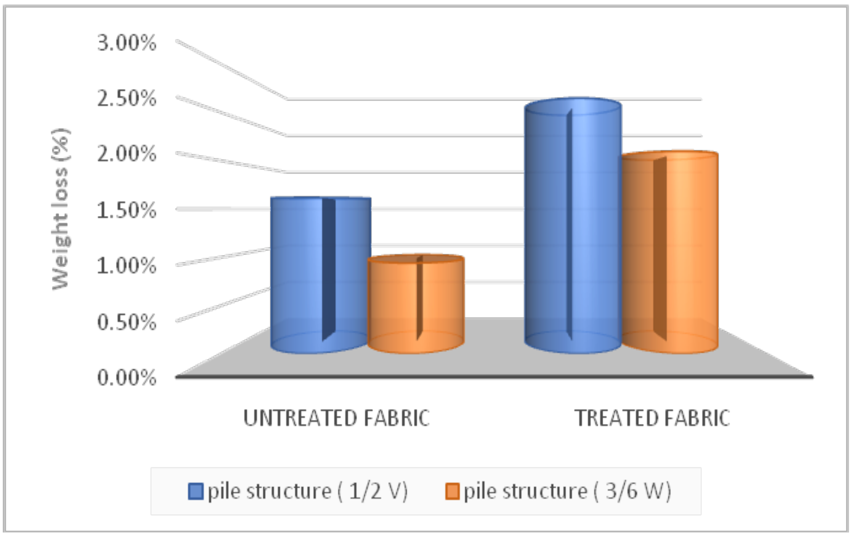


Fig. 10. Relationship between pile structure and Abrasion Resistance.

has recorded the highest rates for warp tensile strength followed by pile structure 3/6W. Because of incrasing the pile density in unit area which leads to an increase in the fricsion between the tufts inside the sample under the jaws of tensile testing machine, as a result the tensile strength in warp direction increased and vice verse.

The results of treated samples was higher than untreated samples.this is due to that, the coating of fluorocarbon compound using in this study has interact in curing step, which lead to increase in the tensile strength of treated samples.

Tensile Strength in Weft Direction

It can be noticed from Figure (12) and Tables (2 & 3) that, there is an inverse relationship between number of pile tufts per unit area and tensile strength in weft direction. Where the pile structure 3/6W has recorded the highest rates of tensile strength in weft direction followed by 1/2V. this is owing to increasing the pile density per unit area at 3/6W (66 tufts /cm^2) is less than the pile density per unit area at 1/2V (200 tufts / cm^2). As number of piles per unit area increase the strain on wefts increased, as a result the tensile strength in weft direction decreased and vice verse.

It clear the treated samples have recorded the highest rates of tensile strength in weft direction, because of the samples becomes more compact after treatment than before treatment, which leads to increase the tensile strength weft direction.

Fabric Air Permeability

Effect of pile structure on air permeability is show in Figure (13) and Table (3), From Figure (13) it can be seen that, the pile structure 3/6 W has recorded the high rates of fabric air permeability followed by pile Structure 1/2 V. This is mainly because of the increase in pile dencity in the weave structure 1/2 V, which lead to decrease in the porosity of the fabric and increases the covering of the fabric surface, so as a result the fabric air permeability decreases[24-26].

Also it can be seen that the untreated sample have recorded the highest rates of air permeability, this is due to the fact that, the treatment materials covering of the fabric surface so the fabric becomes less porosity and hence its air permeability decreased.

Contact Angle Analysis, Water Repellenceand Oil Repellence

It can be noticed from Figure (14) and Table (3) that, the pile structure 3/6 W has recorded the high contact angle followed by pile Structure 1/2 V. This due to the uneven surface topography of sample with pile structure 3/6 W as shown in Figure (6), which lead to decrease the contact point with water drops and the fabric surface. The water and oil repellency of produced fabrics could be enhanced with an increase of surface roughness [27].

Critical surface tension is the good indicator for fluorocarbon treatments. Contact angles are considered an important performance measurement for a Water / oil repellent surface.

Most of fluorochemical agents are fluorine-containing acrylic and /or vinyl copolymers.

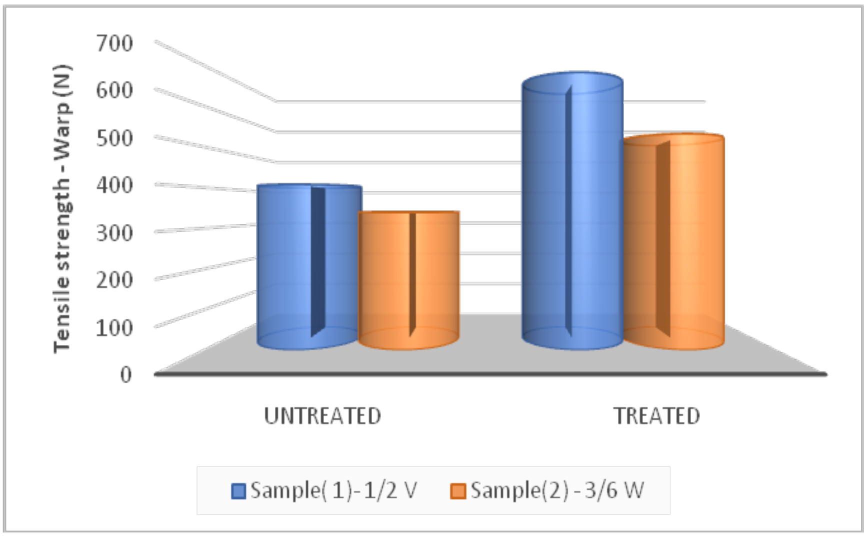


Fig. 11. Relationship between pile structure and Tensile Strength in Warp Direction.

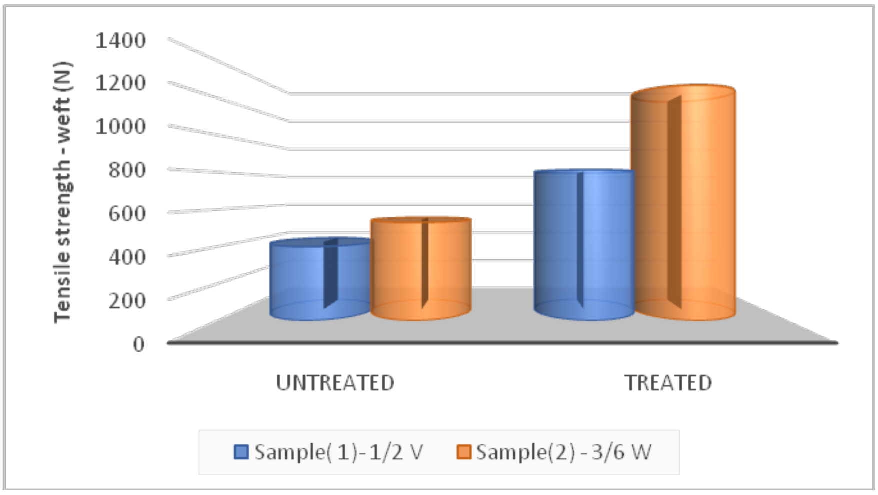


Fig. 12. Relationship between pile structure and Tensile Strength in Weft Direction.

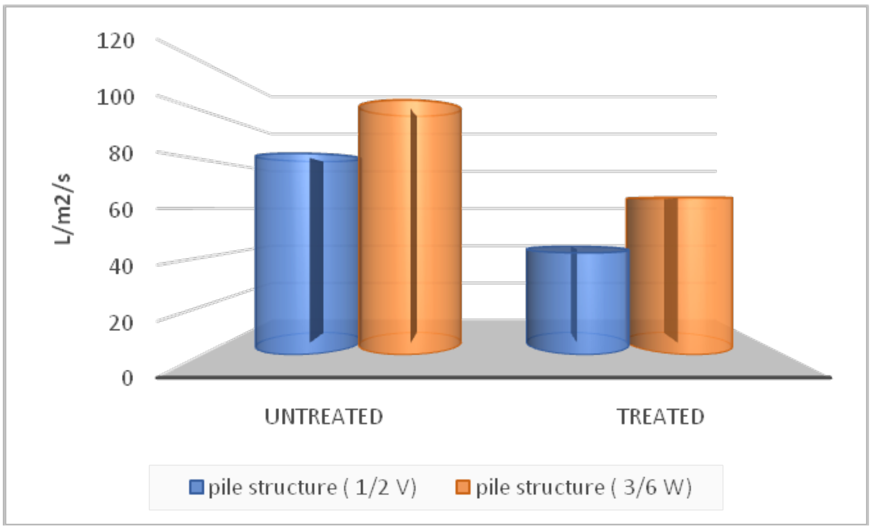


Fig. 13. Relationship between pile structure and Air Permeability.

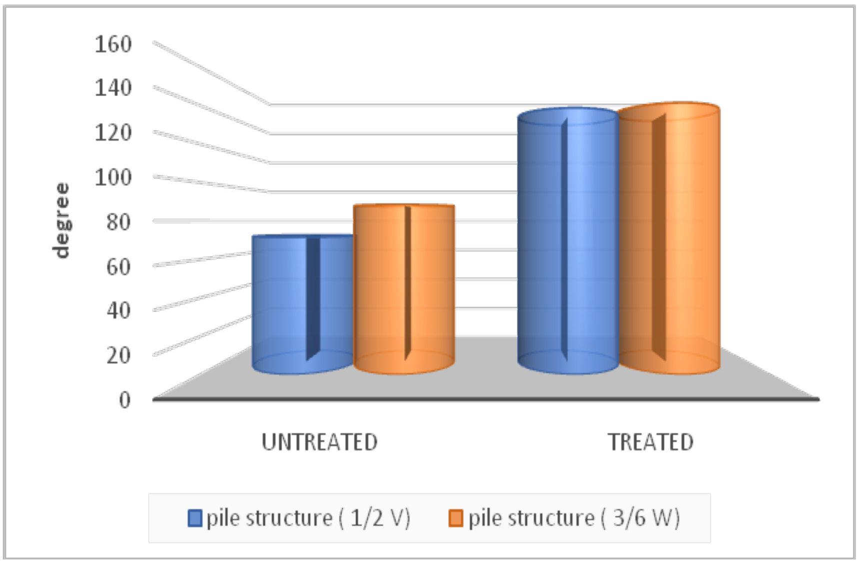


Fig. 14. Relationship between pile structure and Contact angle.

This method is the best of position perfluoro side chains to substrate surfaces that can make moderately CF groups close to surface area, formed closely during curing process is attached onto surface of substrate [14].

From Table (3) and Figure (15) show that the contact angle of production samples before and after finishing treatments is increasing about 48.6 % in sample (1/2 V) and about 37.5 % in sample (3/6 W).

The construction of production fabrics is affected in the critical surface tension of fabrics. The untreated produce fabrics has water/oil repellency properties also, these results clearly indicate that the coating of finishing agent is done, keeping other parameters constant. The data in Table (3) show that using finishing agent (150 g/L), increasing the water/oil repellent in the water repellency and oil repellency properties of treated fabric. the sample with the pile structure (3/6 W), has recorded weight gain 27.2 % and contact angle 141.6^{O} but sample with the pile structure (1/2 V) recorded weight gain 18.4 % contact angle 139^{O}. the decrease in water absorption rate of treated samples could be result of increase of pore volume distribution and swelling of samples.

De et al. and others [28, 29] reported that the fluorochemicals can create a combination of water repellency and oil repellency. Fluoro chemicals act as a coating agent of layer on the substrate surface, which blocks the passage of both vapor and water and resulting in reduced breathability of coating fabrics with fluorochemicals.

Fastness Properties and UV-Protection Factor Analysis

It is clear from Table (4) K/S values of treated produced fabrics in decrease than K/S values untreated. These decreases result from coating the finishing agent in surface of fabrics in curing process.

From K/S values we can found that Fluorocarbon compound as a treatment finishing agent used and the fabrics structure reflect the relationship between them represented in K/S values.

As can be observed from Table (4), wash fastness results of the untreated samples show differences according to treatment and rubbing type. Generally, washing fastness values of the treated produced samples are lower than untreated, rubbing fastness of untreated produced samples are higher than treated, light fastness properties of produced fabrics and treated produced fabrics have slight difference[19].

Çelik et al. [30] suggested that the particle size of finishing agent plays an important role in color and fastness properties for treated fabrics and pore volume of fabrics

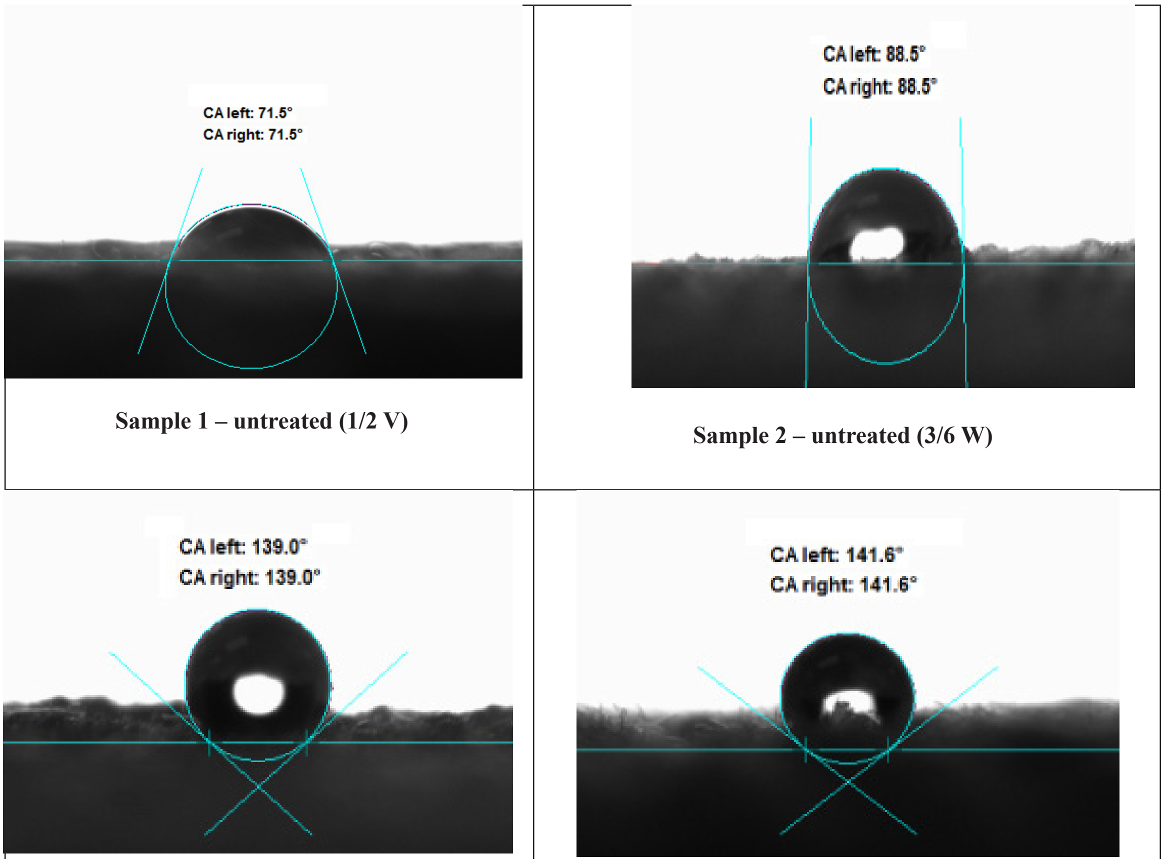
It is clear from Table (4) there is have no higher changes on UPF values in the treated and untreated produced fabrics because the main advantage of velvet fabrics is the cover factor which is the important factor in UV- protection.

The distances between pile, thickness and weight of the material have implications for the degree of protection, whether positive or negative, indicating that weight gain and increased cover rate provide 95 % of the best protection. The produced fabrics generally have no transmission when measuring.

Durability to Laundering

Table (5) shows the effect of laundering on the imparted functional properties for produced velvet fabrics. The imparted functional properties are still durable enough even after laundering test. Laundering has a positive impact on fabric air permeability, contact angle, water repellence and oil repellence but has no change in UPF values. Compared with the treated sample (1/2 V), which had a contact angle of 139, as laundering had 118.9 but in treated sample (3/6 W), which had a contact angle of 141.6, as laundering had 122.3.

Schindler and Hauser reported that the laundering disturbs this orientation and reduces finish performance after curing. That decreased in repellency properties case from when the treated fabrics rinsed in washing or laundering[31].



Sample 1 – untreated (1/2 V)

Sample 2 – untreated (3/6 W)

Sample 3 –treated (1/2 V)

Sample 4 – treated (3/6 W)

Fig. 15. Contact angle of treated & undertreated samples.

TABLE 4. Treated and Untreated Fabrics Testing Results.

S. No.	Treatment	Pile Weave Structure	Testing Results						
					WF		RF		
			K/S	UPF	Alt.	St.	Dry	Wet	LF
1	without	1/2 V	4.18	365	4	4	3-4	3-4	4-5
2	without	3/6 W	3.96	408	4	4	3-4	3	5
3	treated	1/2 V	3.79	320	3-4	3-4	3-4	3-4	4-5
4	treated	3/6 W	2.93	371	3	3-4	3	3	4-5

K/S: color strength, WF: wash fastness: Alt.: alteration of color; St.: staining of white cotton,RF: rubbing fastness;LF: light fastness; UPF: UV- protection factor

TABLE 5. Durability to Laundry Testing Results.

S. No.	Treatment	Pile Weave Structure	Testing Results				
			Air Permeability	Water Repellence	Oil Repellence	Contact Angle	UPF
			L/m²/S	degree	degree	degree	degree
1	treated	1/2 V	64.6 (70.3)	70 (60)	6 (4)	139 (118.9)	320 283
2	treated	3/6 W	41.8 (65.8)	80 (70)	8 (6)	141.6 (122.3)	371 318

Conclusion

The present research concerned with producing two warp pile fabrics with two different structures (1/2 V & 3/6 W) and treated with fluorocarbon finishing agent, in order to study the effect of the fabric structure and chemical treatment on the mechanical and functional properties. Our findings show that, there is a significant relationship between the fabric structure and the tensile strength, abrasion resistance, thickness, fabric weight and air permeability. The samples with the pile structure (1/2 V) have recorded highest rates in the fabric weight, thickness, tensile strength in warp direction. Whiles the samples with the pile structure (3/6 W) have recorded highest rates in abrasion resistance, tensile strength in weft direction and the contact angle with the water drop. In this work, the produced samples were treated with (150 g/L) fluorocarbon compound padded fabric samples at 100 % wet pick-up were followed by drying at 100 °C/5 min, and cured at 170 °C/45 sec. The treated fabrics show that the sample (3/6 W) have contact angle, water and oil repellency higher than the sample (1/2 V) even after 10 laundering cycles.

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