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Effect of Nonionic Surfactant Solutions on Wetting and Absorbency of Polyethylene Terephthalate(PET) Fabrics (Part II) -Surfactants Characteristics and Fabric Properties-

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비이온계 계면활성제 수용액이 PET직물의 습윤특성에 미치는 영향 (제2보) -계면활성제와 직물의 특성-

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Abstract

The wetting behavior and liquid transport of nonionic surfactant solutions; Span 20 and Tween 20, 40, 60, 80, 21, 61, 81, 65 & 85; in polyethylene terephthalate(PET) fabrics are reported. Five different PET fabrics are used in this study. PET 1, 2 & 3 have different compactness in structure. PET 4 & 5 have similar physical properties to PET 2, however, PET 4 has heat set finish and PET 5 with rewetting agent. The wetting and water retention properties of PET fabrics are greatly improved by addition of nonionic surfactants. The aqueous liquid retention(W) vs. cosq and W vs. adhesion tension has positive linear relationship. Hydrophilic surfactants which have short hydrophobes and surfactants with unsaturated hydrophobe structures are more effective in improving the wetting properties of PET fabrics. PET fabric which has larger thread spacing shows greater value of water retention ratio(W/H) than PET fabric with smaller thread spacing if there are no surfactants present in the system, however, W/H values become very similar among these PET fabrics when the surfactants are added. If there are no surfactants present in the system, PET with heat set finish has smaller value and PET with rewetting agent has greater value of W/H than PET without finish even though the fabrics have the similar physical properties.

Key words: Nonionic surfactants, Wetting, Absorbency, PET, Contact angle; 비이온계 계면활성제, 표면적심, 흡수성, 폴리에스터, 접촉각

I. Introduction

When treating textiles by immersion in aqueous solution it is essential to ensure that air be displaced quickly and thoroughly from between the fibers or filaments so as to establish contact between the textile surfaces and the treatment bath(Datyner, 1983). It can be influenced by the wettability of the material itself and the properties of aqueous solutions used.

Span and Tween series surfactants have different solution properties, i.e., hydrophile-lipophile balance (HLB) values, critical micelle concentrations(CMC),

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surface tensions at CMC and packing densities at the interface(Kim, 2000). These surfactants were employed to alter the characteristics of the aqueous liquid and enhance the wetting and wicking of hydrophobic fiber assemblies. The wetting and absorbency of hydrophobic raw cotton fabrics(desized and unscoured) were improved with addition of 0.1 g/dl of any surfactants mentioned above, however, the amounts of aqueous liquid retained in the pore structure were dramatically decreased just below CMC when the surfactant solutions were diluted below CMC(Kim, 2001; Kim & Hsieh, 2000, 2001). Among these surfactants, hydrophilic surfactants which had short hydrophobes and surfactants with unsaturated hydrophobe structures showed better abilities to improve water wetting and retention of raw cotton fabrics than other surfactants(Kim, 2001).

Similar experiments were performed on polyethylene terephthalate(PET) fabrics which had energetically stable surfaces result in low wettable surface characteristics(Kim, 2003). The wettability of PET were improved by various efforts to make chemical or physical changes of PET, i.e., alkaline hydrolysis, enzymatic hydrolysis, or solvent and argon glow discharge treatments, because liquid wetting properties of fibrous materials were crucial to their functional performance, finishing and maintenance processes(Hsieh et al., 1989, 1996; Hsieh & Cram, 1998; Tim & Hsieh, 1993, 1994). Instead of changing fabric itself, we could enhance the wetting and wicking properties of PET fabric by simply adding nonionic surfactants into aqueous liquid(Kim, 2003).

Hsieh, Y-L and Yu, B(Hsieh & Yu, 1992) reported that the overall wetting properties for fabrics were similar to those derived for single fibers and concluded that the water wettability of fabrics was the intrinsic wettability of the constituent fibers and polymers. They also reported that water wetting contact angles of cotton fabrics were not affected by fabric configurations, such as length, fabric-water interface depth, and direction.

Then, whether/how the wetting and absorbency of fabrics are affected by the physical/chemical properties of fabrics, such as fabric count, weight, thickness or after finish and the characteristics of surfactant solutions? In order to investigate the effect of substrate characteristics on wetting and absorbency of nonionic surfactant solutions, five PET fabrics which had different physical properties were used in this study. The liquid properties were altered by adding several nonionic surfactants, i.e., Span 20 and Tween 20, 40, 60, 80, 21, 61, 81, 65 & 85 with concentration of 0.1g/dl and 1.0g/dl to be tested for their influence on wetting and liquid retention properties of PET fabrics. Analysis of the liquid wetting and retention behavior, and their correlation with surfactants and micelle dimensions as well as liquid surface tensions and HLB values provide much insight into the hydrophilic-hydrophobic nature of the fiber surfaces as well as the optimal aqueous transport in these porous media.

II. Experimental

1. Materials

Ten nonionic surfactants, that is, Span 20 and Tween 20, 40, 60, 80, 21, 61, 81, 65 & 85 were obtained from Sigma Chemical Co. The structures, compositions and characteristics of these surfactants were listed elsewhere(Kim, 2000). The surfactants were not isomerically pure and were used as received without further purification. The surface tensions were measured using tensiometer(K14, KRUSS) at 21°C, since the nonionic surfactants have low Krafft points.

Five plain-weave 100% PET fabrics were used in this study. PET 1, 2 & 3 had different fabric count and yarn numbers(#777, Dacron54 homopolymer, spun yarn, Testfabrics, Inc.). PET 4(#777H) and PET5(#761) had similar physical properties with PET 2, however, PET 4 had heat set finish and PET 5 rewetting agent in it. Certified grade hexadecane (g=26.7 dyne/cm) from Fisher Scientific and Millipore Milli-Q water system purified water(γ=72.6 dyne/cm and pH=6.2) were used.

2. Fabric Preparation

Each fabric samples were cut and raveled to a dimension of 6.35cm×12.7cm. All fabrics except PET 5 were thoroughly cleaned with trichlorotrifluoroethane to remove surface impurities and residues prior to use. PET 5 was used as received without organic solvent cleaning which could dissolve rewetting agents present in PET 5. Solvent treatment were performed for 2 minutes and air-dried for 3 minutes at room temperature which was followed by the same procedure once again on the same sample. After 10 minutes drying in fume hood, sample fabrics were conditioned at 20 and 65% RH for 72 hours prior to testing. Fabric weight, count and thickness were measured by standard methods.

3. Contact Angle and Liquid Retention Measurements

The liquid wetting and retention properties of the PET fabrics were measured by the previously described methods(Kim, 2001, 2003). Fabric samples were cut into the dimension of 6.35mm by 25.4mm in a warp direction. Each specimen was forced to contact with a surfactant solution to measure the stabilized balance reading(ΔB_{st}) and it was separated from the surfactant solution to measure the amount of liquid retained by each specimen($\Delta B_{sp} = W_l$). The fabric wetting force(F_w) was decoupled as:

$$F_w = (\Delta B_{st} - \Delta B_{sp})\, g = (\Delta B_{st} - W_l)\, g \qquad (9)$$

Where g is the gravitational acceleration. The fabric wetting contact angle(θ) was calculated from the wetting force(F_w):

$$F_w = p\gamma\cos\theta \qquad (10)$$

$$\theta = \cos^{-1}\left(\frac{F_w}{p\gamma}\right) \qquad (11)$$

Where p is the fabric-liquid perimeter, γ is the liquid surface tension, and $\gamma \times \cos\theta$ is the adhesion tension.

The specimen was then dried and conditioned at 20°C and 65% RH for 48 hours before being measured in a total wetting liquid, hexadecane, to estimate p value:

$$p = \frac{F_w}{\gamma_{hexadecane}} \qquad (12)$$

Where cosθ is assumed to be 1.

The work of adhesion(W_{ad}) is given by as follows:

$$W_{ad} = \gamma_{fa} + \gamma_{la} - \gamma_{fl} \qquad (13)$$

Where γ_{fa}, γ_{la}, and γ_{fl} are the interfacial tensions at fabric/air, liquid/air and fabric/liquid interfaces, respectively. The following equation is used for the system of fabric contact with both liquid and air :

$$\gamma_{fa} = \gamma_{fl} + \gamma_{la}\cos\theta \qquad (14)$$

By combining equations (13) and (14), W_{ad} is expressed as follows:

$$W_{ad} = \gamma(1 + \cos\theta) \qquad (15)$$

The vertical liquid retention capacity for hexadecane(H, μl/mg) and aqueous surfactant solutions(W, μl/mg) were calculated from dividing the total mass of the liquid retained in hexadecane(W_{hexa}) and in aqueous surfactant solution(W_{surf}) respectively by the liquid density(ρ) and the fabric weight(W_{fabric}). The density of surfactant solutions was assumed to be the same as that of water since the total surfactant concentration was dilute enough to justify this assumption.

$$H = \frac{W_{hexa}}{\rho_{water} W_{fabric}} \qquad (16)$$

$$W = \frac{W_{surf}}{\rho_{water} W_{fabric}} \qquad (17)$$

The ratio W/H was used to quantify the amount of aqueous surfactant solutions retained in the fabric relative to the hexadecane capacity of the same fabric.

4. Fabrics and Surfactants Characteristics

<Table 1> shows the fabric characteristics and the water wetting and retention properties of five PET fabrics. Among PET 1, 2 & 3, PET 1 is the finest and PET 3 is the coarsest. PET 4 and 5 have the similar fineness with PET 2, however, PET 4 has heat set finish and PET 5 rewetting agent. The liquid wetting and retention properties of PET 5 are decreased after cleaning with trichlorotrifluoroethane possibly because o-phenylphenol(OPP) used as rewetting agent is washed out with organic solvents. Therefore PET 5 is used as received without further cleaning process to see the effect of after finish on wetting and absorbency of PET

Table 1. Physical and water wetting & retention properties of PET fabrics

Characteristics	PET 1	PET 2	PET 3	PET 4 (heat set)	PET 5(w/rewetting agent)	
					as received	cleaned
Fabric count, warp×filling(yarn/inch)	72×77	51×53	40×32	49×54	48×53	48×53
Fabric weight(mg/cm^2)	11.3	12.3	16.9	12.2	12.1	12.1
Fabric thickness(μm)	276.4	332.1	416.1	317.5	306.3	306.3
Water contact angle, θ(°)	78.7	71.3	72.1	77.3	61.6	80.2
Cosθ	0.1966	0.3213	0.3080	0.2193	0.4756	0.1711
Liquid retention capacity, H(μl/mg)	1.39	1.65	1.27	1.12	1.46	1.52
Water retention, W(μl/mg)	0.10	0.46	0.31	0.19	0.75	0.05
Water/Hexadecane ratio, W/H	0.07	0.28	0.25	0.17	0.51	0.04

fabrics.

Hydophile-lipophile balance(HLB) and molecular area values of Span 20 and Tween series surfactants are reported in the earlier paper(Kim, 2000). Span 20 is the most hydrophobic(lipophilic) and Tween 20 is the most hydrophilic among all the surfactants used. Hydrophilicity is decreased with increasing carbon atoms in hydrophobe tails and slightly increased if hydrophobe tail has unsaturated structure. Tween 21 is less hydrophilic than Tween 20 because the former has only 4 moles of ethylene oxide units compared with the latter which has 20 moles of ethylene oxide units as hydrophile. Tween 65 is less hydrophilic than Tween 60 due to three hydrophobe tails present in Tween 65, whereas Tween 60 has only one hydrophobe tail.

III. Results and discussion

1. Wetting and Water Retention Properties of PET 1 with 0.1 & 1.0 g/dL Surfactant Solutions

Both 0.1 and 1.0 g/dl surfactant solutions are above CMC. <Table 2> shows the wetting and liquid retention properties of PET 1 fabric with 0.1g/dl surfactant solutions. Contact angles(θ's) are decreased and water retention ratios(W/H) are increased with surfactants addition to the system. The improvement effect of wetting and absorbency of PET fabric is much greater than that of cotton fabric(Kim, 2001; Kim & Hsieh, 2000, 2001). The θ's are in the range of 39.1-78.2 and W/H are 0.06-0.35 in cotton fabric with 0.1g/dl surfactant solutions, which means only 6-35% of pore capacity are filled with water when the nonionic surfactants added(Kim, 2001). Whereas the θ's and W/H values of PET 1 fabric are 14.5-60.9 and 0.22-1.00 respectively, possibly because PET fabric has simple pore structure which enables water wicked easily. Tween 20, 40, 60, & 80, which have 20 moles of ethylene oxide(EO) units, show very low value of q and high value of W/H. Tween 80, which has unsaturated hydrophobe structure, is the most effective in wetting and liquid retention properties of PET 1 fabric. Tween 21, 61, and 81, which have 4 moles of EO units added, show somewhat different results. Tween 21 show similar value of q and W/H to Tween 20, however, Tween 61 is much less effective than Tween 60 and Tween 81 is more effective than Tween 80 in wetting and water retention of PET 1 fabric. The hydrophobic effect becomes greater in Tween 61 than in Tween 60 due to less amount of EO even though they both have the same hydrophobe structure. Tween 81 has less EO's than Tween 80, however, it does not affect much to the results. Tween 65 and 85 show similar result to Tween 61 and 81. Tween 65 shows high value of q and low value of W/H and Tween 85 low value of q and very high value of W/H. Unsaturated hydrophobe structure is more important than just HLB values in improving wetting and water retention properties of PET 1 fabric.

The results with 1.0g/dl surfactant solution are listed in (Table 3). Span 20, Tween 21, 61, & 65 are too hydrophobic to make 1.0g/dl aqueous surfactant solutions. Even though the HLB values of Tween 81 & 85 are low, both of them are water soluble enough to make 1.0g/dl solutions. The θ and W/H of 1.0g/dl surfactant solutions are comparable with those of 0.1g/dl concentrations. Wetting and absorbency of

Table 2. Wetting and retention properties of PET 1 fabric with 0.1g/dl surfactant solutions

Surfactants	0.1g/dl aqueous solution							
	Surface tension (dyne/cm)	CMC (moles/L)	Molar concentration (moles/L)	θ (°)	W (μl/mg)	H (μl/mg)	W/H	Wad
Water	72.6			78.7 (2.68)	0.10 (0.02)	1.39 (0.05)	0.07 (0.02)	86.9
Span 20	26.7	6.13×10^{-5}	2.89×10^{-3}	33.4 (2.78)	1.10 (0.05)	1.31 (0.03)	0.84 (0.05)	48.9
Tween 20	38.0	8.04×10^{-5}	8.16×10^{-4}	39.4 (0.60)	1.31 (0.03)	1.37 (0.05)	0.96 (0.03)	67.4
Tween 40	36.7	1.68×10^{-4}	7.79×10^{-4}	24.1 (2.15)	0.96 (0.05)	1.28 (0.03)	0.75 (0.02)	70.3
Tween 60	41.4	1.21×10^{-4}	7.63×10^{-4}	24.0 (1.64)	1.09 (0.09)	1.27 (0.08)	0.86 (0.01)	79.2
Tween 80	35.9	8.87×10^{-5}	7.64×10^{-4}	22.8 (3.32)	1.36 (0.06)	1.36 (0.06)	0.99 (0.03)	69.0
Tween 21	35.4	1.16×10^{-4}	1.92×10^{-3}	33.0 (3.66)	1.19 (0.02)	1.36 (0.02)	0.87 (0.01)	65.0
Tween 61	37.1	9.66×10^{-5}	1.65×10^{-3}	60.9 (3.17)	0.30 (0.07)	1.36 (0.04)	0.22 (0.05)	55.1
Tween 81	33.0	1.27×10^{-3}	1.54×10^{-3}	14.5 (1.10)	1.21 (0.03)	1.30 (0.04)	0.94 (0.01)	64.9
Tween 65	37.8	3.72×10^{-5}	4.89×10^{-4}	50.5 (1.31)	0.33 (0.02)	1.33 (0.09)	0.25 (0.01)	61.8
Tween 85	40.1	9.80×10^{-5}	4.90×10^{-4}	32.1 (1.98)	1.33 (0.07)	1.32 (0.08)	1.00 (0.01)	74.0

*( ) represent standard deviations

Table 3. Wetting and retention properties of PET 1 fabric with 1.0g/dl surfactant solutions

Surfactants	1.0g/dl aqueous solution							
	Surface tension (dyne/cm)	CMC (moles/L)	Molar concentration (moles/L)	θ (°)	W (μl/mg)	H (il/mg)	W/H	Wad
Water	72.6			78.7 (2.68)	0.10 (0.02)	1.39 (0.05)	0.07 (0.02)	86.9
Span 20								
Tween 20	37.9	8.04×10^{-5}	8.16×10^{-3}	24.9 (1.46)	1.38 (0.05)	1.38 (0.04)	1.00 (0.01)	72.3
Tween 40	36.5	1.68×10^{-4}	7.79×10^{-3}	24.6 (2.61)	1.20 (0.04)	1.30 (0.05)	0.93 (0.02)	69.7
Tween 60	39.8	1.21×10^{-4}	7.63×10^{-3}	23.5 (0.66)	1.19 (0.03)	1.17 (0.00)	1.01 (0.02)	76.3
Tween 80	38.9	8.87×10^{-5}	7.64×10^{-3}	27.7 (1.19)	1.29 (0.03)	1.29 (0.03)	1.00 (0.01)	73.3
Tween 21								
Tween 61								
Tween 81	33.2	1.27×10^{-3}	1.54×10^{-2}	24.7 (1.59)	1.30 (0.06)	1.34 (0.04)	0.97 (0.02)	63.4
Tween 65								
Tween 85	41.2	9.80×10^{-5}	4.90×10^{-3}	41.0 (0.56)	1.35 (0.04)	1.36 (0.05)	0.99 (0.00)	72.3

*( ) represent standard deviations

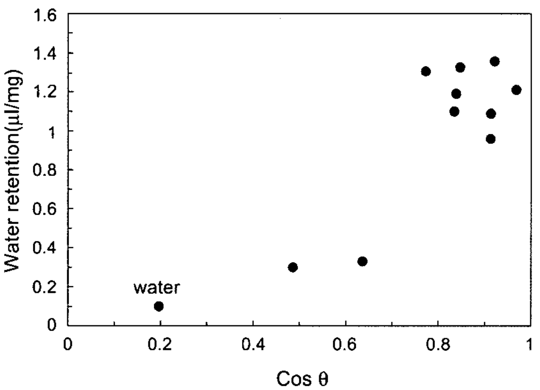

Fig. 1. Cosθ vs. water retention values for PET 1 fabric in 0.1g/dl Span 20 and Tween series nonionic surfactant systems

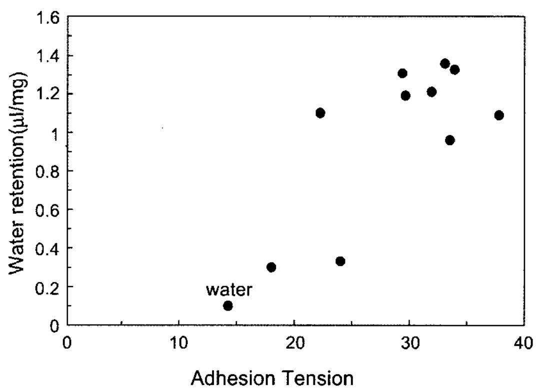

Fig. 2. Adhesion tension vs. water retention values for PET 1 fabric in 0.1g/dl Span 20 and Tween series nonionic surfactant systems

PET 1 fabric are not greatly improved even though the surfactant concentrations become ten times higher than before, therefore 0.1g/dl is high enough concentration since it is greater than CMC.

Water retention increases linearly with Cosθ or adhesion tension roughly <Fig. 1, 2>, which is observed repeatedly in other research(Kim, 2001; Hsieh et al., 1996; Hsieh & Cram, 1998).

2. Effect of Physical Properties of Fabric on Wetting and Water Retention Properties

<Table 4> show wetting and water retention properties of three PET fabrics. PET 1, 2 & 3 have different fabric count, where PET 1 is the finest structure and PET 3 is the coarsest. W/H value without surfactants is 0.07 for PET 1, 0.28 for PET 2 and 0.25 for PET 3, however, W/H values become very similar among these three PET fabrics when the surfactants are added to the system. It is presumably because that the mass of liquid retained in the pore is affected by thread spacing if there are no surfactants(Hsieh, 1995), however, it is affected by water in surfactants micelles once the surfactants are added and are compatible with the substrate. The effects of surfactants in improving absorbency of PET fabrics are much more profound than that of cotton fabric(Kim, 2001). PET 2 & 3 show the similar results with PET 1, that is, hydrophilic surfactants are effective and the surfactants with unsaturated tail structures, such as Tween 80, 81 & 85, are especially effective in wetting and water retention of PET fabrics, whereas hydrophobic surfactants, such as Tween 61 & 65, are not effective in wetting and absorbency of PET fabrics.

3. Effect of after Finish done on the Fabric on Wetting and Water Retention Properties

PET 2, 4 & 5 have similar physical structures but different finish, that is, PET 2 has no finish, PET 4 heat set finish and PET 5 rewetting agent added (Table 5). Even though the fabrics have the similar structure, PET 4 has smaller value and PET 5 has greater value of W/H than PET 2 when there are no surfactants present in the system. Addition of surfactants improves wetting and liquid retention of all three PET fabrics. Tween 80, 81 & 85 are more effective and Tween 61 & 65 are less effective than other surfactants. PET 5 shows quite good value of W/H with Tween 61 & 65, which means the fabric with rewetting agent is less affected by the surfactant characteristics.

IV. Conclusion

Surface wetting and water retention properties are fundamentally important to many industrial processes and to the performance of textile materials. In order to improve the wetting and absorbency of five PET fabrics which have different physical properties and after finish, Span and Tween series of nonionic surfactants are added to the aqueous system. PET 1, 2 & 3 have different fabric count and thickness. PET 4 & 5 have similar physical structure to PET 2, however, PET 4 has heat set finish and PET 5 rewetting agent.

The wetting and water retention of PET 1 is greatly improved with addition of any surfactants, however, Tween 61 & 65 which have hydrophobic characteristics give the least effective and Tween 81 & 85 which have unsaturated hydrophobe tail the most effective results. The wetting and absorbency of PET 1 are not much improved with 1.0g/dl compared with 0.1g/dl surfactant concentrations, where both concentrations are above CMC. Water retention increases with Cosθ or adhesion tension indicating that improved wetting property plays a primary role in improving the water retention properties of the fabrics.

PET 2 & 3 show greater value of water retention ratio(W/H) than PET 1 without surfactants, presumably due to the thread spacing and other physical properties of the material. W/H values become very similar among these PET fabrics when the surfactants are added because of the micelles present in the systems. Hydrophilic surfactants are effective and the surfactants with unsaturated tail structures are especially effective in wetting and water retention, whereas hydrophobic surfactants does not improve

Table 4. Wetting and retention properties of PET fabrics with 0.1g/dl surfactant solutions

	PET 1					PET 2					PET 3				
	θ (°)	W (μl/mg)	H (μl/mg)	W/H	Wad	θ (°)	W (μl/mg)	H (μl/mg)	W/H	Wad	θ (°)	W (μl/mg)	H (μl/mg)	W/H	Wad
Water	78.7 (2.68)	0.10 (0.02)	1.39 (0.05)	0.07 (0.02)	86.9	71.3 (3.11)	0.46 (0.17)	1.65 (0.09)	0.28 (0.11)	95.9	72.1 (3.19)	0.31 (0.06)	1.27 (0.02)	0.25 (0.05)	95.0
Span 20	33.4 (2.78)	1.10 (0.05)	1.31 (0.03)	0.84 (0.05)	48.9	34.7 (3.00)	1.38 (0.03)	1.70 (0.12)	0.82 (0.06)	48.6	34.4 (2.49)	1.08 (0.05)	1.24 (0.05)	0.87 (0.01)	48.6
Tween 20	39.4 (0.60)	1.31 (0.03)	1.37 (0.05)	0.96 (0.03)	67.4	38.3 (0.89)	1.68 (0.08)	1.70 (0.08)	0.99 (0.01)	67.9	41.1 (0.78)	1.23 (0.03)	1.26 (0.04)	0.97 (0.00)	66.7
Tween 40	24.1 (2.15)	0.96 (0.05)	1.28 (0.03)	0.75 (0.02)	70.3	30.7 (3.65)	1.22 (0.09)	1.63 (0.05)	0.75 (0.07)	68.3	30.6 (2.58)	1.15 (0.03)	1.26 (0.02)	0.92 (0.01)	68.3
Tween 60	24.0 (1.64)	1.09 (0.09)	1.27 (0.08)	0.86 (0.01)	79.2	29.7 (1.66)	1.03 (0.21)	1.55 (0.10)	0.66 (0.10)	77.3	24.5 (2.25)	1.16 (0.02)	1.19 (0.04)	0.97 (0.02)	79.0
Tween 80	22.8 (3.32)	1.36 (0.06)	1.36 (0.06)	0.99 (0.03)	69.0	23.7 (1.42)	1.70 (0.04)	1.65 (0.04)	1.03 (0.01)	68.8	26.8 (1.12)	1.21 (0.04)	1.22 (0.04)	0.99 (0.01)	68.0
Tween 21	33.0 (3.66)	1.19 (0.02)	1.36 (0.02)	0.87 (0.01)	65.0	38.0 (1.46)	1.37 (0.10)	1.64 (0.11)	0.84 (0.02)	63.2	32.7 (1.55)	1.17 (0.05)	1.32 (0.04)	0.89 (0.01)	65.1
Tween 61	60.9 (3.17)	0.30 (0.07)	1.36 (0.04)	0.22 (0.05)	55.1	69.9 (1.72)	0.25 (0.09)	1.72 (0.05)	0.15 (0.05)	49.8	47.6 (3.15)	0.81 (0.02)	1.19 (0.07)	0.67 (0.03)	62.1
Tween 81	14.5 (1.10)	1.21 (0.03)	1.30 (0.04)	0.94 (0.01)	64.9	θ<0	1.61 (0.06)	1.65 (0.04)	0.98 (0.02)	x	θ<0	1.21 (0.07)	1.24 (0.08)	0.98 (0.01)	x
Tween 65	50.5 (1.31)	0.33 (0.02)	1.33 (0.09)	0.25 (0.01)	61.8	60.1 (1.36)	0.31 (0.05)	1.64 (0.06)	0.19 (0.03)	56.6	57.1 (0.93)	0.86 (0.04)	1.25 (0.03)	0.69 (0.02)	58.3
Tween 85	32.1 (1.98)	1.33 (0.07)	1.32 (0.08)	1.00 (0.01)	74.0	33.89 (1.68)	1.72 (0.04)	1.65 (0.05)	1.04 (0.01)	73.3	34.8 (0.80)	1.25 (0.02)	1.23 (0.02)	1.01 (0.01)	73.0

* ( ) represent standard deviations

Table 5. Wetting and retention properties of PET fabrics with 0.1g/dl surfactant solutions

	PET 2					PET 4 (heat set)					PET 5 (w/rewetting agent)				
	θ (°)	W (μl/mg)	H (μl/mg)	W/H	Wad	θ (°)	W (μl/mg)	H (μl/mg)	W/H	Wad	θ (°)	W (μl/mg)	H (μl/mg)	W/H	Wad
Water	71.3 (3.11)	0.46 (0.17)	1.65 (0.09)	0.28 (0.11)	95.9	77.3 (4.56)	0.19 (0.05)	1.12 (0.04)	0.17 (0.05)	88.5	61.6 (4.90)	0.75 (0.02)	1.46 (0.04)	0.51 (0.02)	107.1
Span 20	34.7 (3.00)	1.38 (0.03)	1.70 (0.12)	0.82 (0.06)	48.6	32.2 (2.02)	0.74 (0.03)	1.12 (0.06)	0.66 (0.03)	49.2	27.1 (1.43)	1.27 (0.04)	1.42 (0.04)	0.90 (0.01)	50.4
Tween 20	38.3 (0.89)	1.68 (0.08)	1.70 (0.08)	0.99 (0.01)	67.9	38.6 (2.96)	1.02 (0.11)	1.01 (0.04)	0.93 (0.08)	67.7	41.4 (0.59)	1.40 (0.05)	1.46 (0.05)	0.96 (0.03)	66.5
Tween 40	30.7 (3.65)	1.22 (0.09)	1.63 (0.05)	0.75 (0.07)	68.3	37.6 (0.67)	0.76 (0.04)	1.10 (0.03)	0.69 (0.04)	65.8	33.5 (1.49)	1.31 (0.07)	1.37 (0.07)	0.95 (0.00)	67.4
Tween 60	29.7 (1.66)	1.03 (0.21)	1.55 (0.10)	0.66 (0.10)	77.3	38.4 (2.63)	0.81 (0.04)	1.12 (0.05)	0.72 (0.02)	73.8	26.9 (0.34)	1.33 (0.04)	1.32 (0.07)	1.01 (0.03)	78.3
Tween 80	23.7 (1.42)	1.70 (0.04)	1.65 (0.04)	1.03 (0.01)	68.8	30.3 (0.76)	1.04 (0.04)	1.09 (0.03)	0.95 (0.01)	66.9	27.7 (1.40)	1.46 (0.03)	1.45 (0.03)	1.01 (0.02)	67.7
Tween 21	38.0 (1.46)	1.37 (0.10)	1.64 (0.11)	0.84 (0.02)	63.2	38.7 (1.69)	0.96 (0.07)	1.11 (0.06)	0.86 (0.04)	63.0	36.2 (2.40)	1.21 (0.02)	1.41 (0.04)	0.86 (0.03)	63.9
Tween 61	69.9 (1.72)	0.25 (0.09)	1.72 (0.05)	0.15 (0.05)	49.8	65.3 (2.16)	0.43 (0.08)	1.16 (0.07)	0.37 (0.08)	52.6	45.5 (1.98)	1.08 (0.05)	1.43 (0.01)	0.76 (0.04)	63.1
Tween 81	θ<0	1.61 (0.06)	1.65 (0.04)	0.98 (0.02)	x	θ<0	0.97 (0.03)	1.16 (0.02)	0.84 (0.04)	x	θ<0	1.33 (0.01)	1.36 (0.02)	0.97 (0.00)	x
Tween 65	60.1 (1.36)	0.31 (0.05)	1.64 (0.06)	0.19 (0.03)	56.6	61.4 (0.79)	0.53 (0.04)	1.12 (0.06)	0.47 (0.03)	55.8	53.9 (2.44)	1.12 (0.03)	1.41 (0.08)	0.79 (0.03)	60.0
Tween 85	33.89(1.68)	1.72 (0.04)	1.65 (0.05)	1.04 (0.01)	73.3	36.6 (0.99)	1.03 (0.03)	1.05 (0.02)	0.98 (0.01)	72.2	36.7 (1.45)	1.38 (0.03)	1.40 (0.03)	0.99 (0.01)	72.2

*( ) represent standard deviations

much of the wetting and wicking of all three PET fabrics.

Without surfactants, PET 4 has smaller value and PET 5 has greater value of W/H than PET 2 even though the fabrics have the similar physical dimensions. The wetting and retention properties of PET 5 are fairly improved with hydrophobic surfactants unlike other PET fabrics. Addition of rewetting agent to PET fabric enables the fabric more wettable and less influenced by the surfactant characteristics than other PET fabrics without rewetting agent.

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요 약

비이온계 계면활성제인 Span 20, Tween 20, 40, 60, 80, 21, 61, 81, 65, 85 수용액이 PET직물의 습윤특성에 미치는 영향을 연구하였다. 5종류의 PET직물이 사용되었는데, PET 1, 2, 3은 밀도, 두께 등이 서로 다르고 가공은 되어 있지 않고, PET 4와 PET 5는 물리적 특성이 PET 2와 비슷한데 PET 4는 heat set 가공이 되어 있고 PET 5는 rewetting agent가 첨가되어 있다. PET직물의 습윤특성은 비이온계 계면활성제가 첨가되면 크게 향상되며, 수분 보유량은 cosθ와 adhesion tension과 정의 상관관계를 보여준다. 친유기가 짧은 친수성 계면활성제나 불포화탄화수소 친유기 구조를 가진 계면활성제가 PET직물의 습윤특성 향상에 효과적이다. 계면활성제가 없을 경우 수분 보유량비(W/H)는 실 간 간격이 넓은 PET직물이 작은 직물보다 컸으나, 비이온계 계면활성제를 첨가할 경우 W/H는 실 간 간격에 관계 없이 유사해졌다. 물리적 특성이 비슷해도 heat set 가공이 되어 있는 직물은 가공이 되어 있지 않은 직물보다 W/H 값이 작았고, rewetting agent가 첨가된 직물은 W/H 값이 컸다.