EFFECT OF PRODUCTION PARAMETERS OF POLYESTER WEFT YARNS ON SOME THERMAL COMFORT PROPERTIES OF DRAPERY FABRICS

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Scientific paper
UDC: 677-037:678.6:62-97:684.7
DOI: 10.5937/tekstind2302023C

Abstract: *This study has been performed to investigate the effect some weft yarn properties such as weft yarn type, fiber cross sectional shape of the yarn and the incorporated* TiO_2 *amount (%) during yarn spinning process on some thermal comfort properties of drapery fabrics such as thermal, air permeability and water vapor permeability properties. 12 woven drapery fabrics were produced by using 334/192 denier/fil draw textured polyester and 400/192 denier/fil air jet textured polyester weft yarns produced with different fiber cross sectional shape (round, hollow) and different amount of incorporated* TiO_2 *additive (0.3%, 1.2%, 1.8%) and with the same 150 denier Trevira yarns at the weft density of 26 threads/cm. SPSS Statistical software package and bar graphs were utilized for the evaluation of the results. Randomized three-way ANOVA was utilized at the significance level of 0.05. And SNK tests were also performed for observing the means of each parameter.*

Key words: Drapery fabrics, fiber cross sectional shape, yarn linear density, thermal comfort.

EFEKAT PROIZVODNIH PARAMETARA POLIESTERSKIH PREĐA NA TOPLOTNA SVOJSTVA I UDOBNOST TKANINA ZA DRAPERIJE

Apstrakt: *Ova studija je sprovedena da bi se istražio uticaj nekih svojstava pređe potke, kao što su tip pređe potke, oblik poprečnog preseka vlakana i količina inkorporirane* TiO_2 *(%) tokom procesa predenja prediva na neka svojstva toplotne udobnosti tkanina za draperije, kao što su termičke, svojstva propustljivosti vazduha i propustljivosti vodene pare. 12 tkanih tkanina za draperije proizvedeno je korišćenjem teksturiranog poliestera 334/192 denier/fil drav i 400/192 denier/fil teksturiranih poliesterskih prediva potke proizvedenih sa različitim oblikom poprečnog preseka vlakana (okrugla, šuplja) i različitom količinom ugrađenog* TiO_2 *aditiva (0,3%, 1,2%, 1,8%) i sa istim Trevira predivama od 150 dena pri gustini potke od 26 niti/cm. Za evaluaciju rezultata korišćeni su softverski paket SPSS Statistical i trakasti grafikoni. Randomizovana trosmerna ANOVA je korišćena na nivou značajnosti od 0,05. I SNK testovi su takođe sprovedeni za posmatranje srednjih vrednosti svakog parametra.*

Ključne reči: Tkanine za draperije, oblik poprečnog preseka vlakana, linearna gustina prediva, toplotna udobnost.

1. INTRODUCTION

The fabric properties depend upon its constituent fibers, yarn, and fabric structure. Different raw materials and fabric structures have their own properties. Home textiles are one of the major sub-groups of textile products. Different weave patterns and different fiber types including natural and man-made fibers like cotton, linen, rayon, polyester may be utilized for the drapery fabrics. The superior properties of polyester fiber create an advantage for its common use in drapery fabrics [1]. The requirement for drapery fabrics may be listed as mechanical, dimensional properties as well as comfort properties. The thermal comfort of the fabric may be defined with the movement of heat, moisture, and air.

Although the heat transfer is a combination of conduction, convection and radiation, the heat transfer within the fabric mainly depends on the thermal conduction because of the negligible radiation and convection losses. The total heat transmitted through the fabric may be defined as the sum of the heat conducted through the air gaps and through the fibers [2,3]. Static thermal features may be defined as thermal conductivity, thermal resistance, and thermal absorption. Thermal conductivity indicates the material's ability to conduct heat. Thermal resistance gives an idea about the thermal insulation property of the material. The difference in the temperature across the unit area of fabric of unit thickness is described as the thermal resistance when a unit heat energy flows through the material for a certain time [4-6]. As the objective measure of warm–cool feeling of fabrics, so-called thermal absorptivity b [$W.s^{1/2}/m^2$ K] was introduced by Hes. This parameter allows assessment of the fabric's character in the aspect of its 'cool– warm' feeling [7]. Thermal properties of the drapery fabrics may be investigated at three levels which are macroscopic level, mesoscopic level, and the microscopic level. Macroscopic level includes fabrics' physical and structural characteristics, mesoscopic level includes yarn structure and properties while microscopic level is related to chemical composition and morphological characteristics [2,5,8]. Some heat and moisture transport properties of the drapery fabrics may be varied by using yarn of different linear density and different fiber type in the warp or in the weft wise. Drapery fabrics are usually produced from synthetic yarns such as polyester. Polyester fibers may be modified by bulking or texturing the yarn as well by utilizing new fiber cross section channels such as hollow, round or "w" types [9,10].

Air permeability should also be considered as well for the drapery fabrics. This parameter is influenced from many factors such as fiber cross sectional shape, yarn twist, fabric cover factor, weaving type as well as from finishing processes. Additionally, water vapor transport feature can be examined under two headings: Water vapor permeability and the water vapor resistance. Water vapor permeability reveals the ability to transmit vapor through the fabric while water vapor resistance is related to the air permeability of the fabric. Fiber content, thickness, percentage fiber volume and fabric geometry are the main factors that may affect the water/moisture vapor transmission of textiles [11,12]. There are many investigations related to effect of some production parameters on thermal comfort properties of knitted and woven fabrics. Some researchers have worked on the effects of different yarn properties on thermal comfort behavior [5,13,14]. Matusiak and Sikorski investigated the influence of structure of woven fabrics on their thermal insulation properties. It was concluded in the study that weave and linear density of weft yarn significantly influenced the thermal properties of woven fabrics [15]. Pac et al. studied the effect of fiber morphology, yarn and fabric structure on thermal comfort properties of fabric [16]. Ramakrishnan et al. explained the effect of fiber fineness on thermal resistance of fabrics [17].

Some researches concerning the effect of fibre cross sectional shape on thermal comfort properties of fabrics were also performed; Varshney et al. investigated the effect of profiles of polyester fibres of four different cross-sectional shapes (circular, scalloped oval, tetrakelion and trilobal) on the physiological properties of their fabric. Tyagi et al. studied the thermal comfort properties produced from polyester/viscose and polyester/cotton ring and air jet yarns where circular and trilobal cross sectional polyester fibres were utilized. Manish et.al. [26] investigated the effect of utilizing a tetra channel cross section polyester fibre instead of cotton in a polyester/cotton blended yarn on various handle and thermal properties [3,18, 19].

From the early literature, it is understood that the thermal comfort properties of any drapery fabric may be modified by using various types of fiber cross sectional shape, or by using different weft yarn type at any linear density of warp or weft yarn. With the scope of this work, it is aimed to produce new drapery fabrics with satisfying thermal comfort properties including thermal properties, air permeability and water vapor permeability properties. 12 different drapery fabrics were produced by using 334/192 denier/fil draw textured polyester and 400/192 denier/fil air jet textured polyester weft yarns produced with different production parameters but with the same 150 denier Trevira warp yarns at the weft density of 26 threads/cm for this aim.

2. EXPERIMENTAL

2.1. Materials and Preparation

12 different drapery fabrics were produced by using 334/192 denier/fil draw textured polyester and 400/192 denier/fil air jet textured polyester weft yarns produced with different fibre cross sectional shape (round, hollow) and different amount of incorporated TiO_2 (0.3 %, 1.2 %, 1.8 %) and with the same 150 denier Trevira warp yarns at the weft density of 26 threads/cm . The polyester multifilament weft yarns (334dtex/192 fil, 400dtex/192 fil) utilized in this study were obtained from semi dull polyester (PET) polymer through the melt spinning process. Only the spinneret cross sectional shape and the incorporated TiO_2 amount (%) was altered. BARMAG FDY 21 Multifilament spinning machine was utilized for the process. Details of the production parameters of Black carbon -TiO_2 added pre oriented polyester yarns were indicated in table 1. Black carbon and Titanium Oxide (TiO_2) added Pre (Partially) Oriented yarns were directed to false twisting (AS1-B) and air jet texturing machines (SSM1). The process conditions for the texturizing process are indicated below in table 2. Experimental design of 12 different drapery fabrics produced from these 334/192 denier/fil DTY and 400/192 AJT polyester weft yarns is revealed in Table 3.

Table 2: Texturing process conditions

False twist Texturing	
drawing (W2/W1)	1.63
D/Y (W6)	1.80
Bottom feed (W3)	-6
winding (W4)	-4.8
winding angle (W5)	30
Disc combination	1-6-1
aggregate type	9 mm
pressure (BAR)	0.5
T1 temperature (°C)	190
T2 temperature (°C)	180

Air-jet Texturing	
Core drawing	1.30
Effect drawing	1.30
Oven temperature (°C)	160°C
Godet temperature (core) (°C)	150°C
Godet temperature (effect) (°C)	150°C
Overfeed core %	10
Overfeed effect %	10
Jet type	T 321
Pressure (BAR)	6

Table 1: Polyester yarn spinning conditions

Extruder Temperature (°C)	**1st region**	**2nd region**	**3rd region**	**4th region**	**difil**
	286 (°C)	**286 (°C)**	**286 (°C)**	**286 (°C)**	**286 (°C)**
Winder speed (mpm)	3000				
1st Godet speed (m/min)	2800				
2nd Godet speed (m/min)	2970				
Melting pomp (rpm)	11.55				
Oil pomp (rpm/oil type)	40/mineral oil				
Nozzle pressure (bar)	135				

Table 3: Experimental design of fabrics produced from partially oriented yarns with different production parameters

Fabric code	Fibre cross sectional shape	Incorporated TiO$_2$ (%)	Incorporated Black carbon (%)	Weft Yarn type (denier/fil)	Weft density (threads/cm)	Warp yarn type	Warp density (threads/cm)
C1	Round	0.3 TiO$_2$	1.05	334/192 PES (DTY)	26	50 denier	112
C2		1.2TİO$_2$					
C3		1.8TİO$_2$					
C4	Hollow	0.3 TiO$_2$					
C5		1.2TİO$_2$					
C6		1.8TİO$_2$					
C7	Round	0.3 TiO$_2$		400/192 PES (AJT)			
C8		1.2TİO$_2$					
C9		1.8TİO$_2$					
C10	Hollow	0.3 TiO$_2$					
C11		1.2TİO$_2$					
C12		1.8TİO$_2$					

2.2. Method

The samples were conditioned for 24 h in standard atmospheric conditions (at the temperature of 20 ± 2 °C and relative humidity of 65 ± 2%) before the performed tests. Drapery fabrics' thermal comfort performance should be evaluated considering that they may be utilized in hot and cold climates in front of the windows. Their windproof performance should also be considered associating with fabrics' structural properties. Hence thermal properties, air permeability and water vapor permeability properties were evaluated by using Alambeta device, SDL Atlas Digital Air Permeability Tester Model M021 A and Permetest devices respectively which are placed in the laboratory of_Textile Engineering Department, Bursa Uludağ University. Each measurement was performed according to related standard indicated in table 4 below. Thermal properties were evaluated in terms of thermal conductivity *(λ)*, Thermal diffusivity *(a)*, Thermal absorptivity *(b)*, Thermal resistance *(r)* results of samples. SDL Atlas Digital Air Permeability Tester Model M 021 A was benefited from for air permeability measurement according to test standard of EN ISO 9237. Measurements were performed by application under 100 Pa air pressure per 20 cm^2 fabric surface. Averages of measurements from 5 averages of measurements from 5 different areas of fabrics were calculated [20,21].

Relative water vapor permeability (RWP %) and absolute water vapor permeability (AWP) of drapery samples were measured via the PERMETEST device in the unit of m^{2}Pa/W. This instrument is able to determine non-destructive measurement of the samples according to ISO 11092 standard and it works on the principle of heat flux sensing. The relative water vapor permeability (RWP) of the sample is calculated by the ratio of heat loss from the measuring head with fabric (q_s) and heat loss from the measuring head without fabric (q_o) as below equation 1 [22-24].

$$RWP = (q_s / q_o) \times 100 \% \tag{1}$$

Table 4: Test type and the standards

Measurement	**Device and Standard**
Thermal Properties	Alambeta
Water vapor permeability	Permetest, TS EN ISO 11092
Air permeability	SDL ATLAS, TS 391 EN ISO 9237

2.3. Statistical Analysis

Analysis of variance method is well known statistical method and is employed to recognize the influential process parameter. The significance of the model parameters can be identified by the use of p-value which is less than α level of significance (5% theoretically). Completely randomized three factor analysis of variance (ANOVA) was performed for determining the effect of weft yarn type, fiber cross sectional shape, incorporated TiO_2 amount (%) of weft yarns on drapery fabrics' thermal, water vapor permeability and air permeability properties. The means were compared by means of SNK tests. The treatment levels revealed by a different letter (a, b, c) show that they were different from each other at significance level of 0.05. The statistical evaluations were performed by using SPSS 23 Statistical software package.

3. RESULTS AND DISCUSSION

3.1. Thermal Properties

Figure 1 indicates the thermal conductivity results of drapery fabrics. According to figure 1, thermal conductivity of samples with 334/192 dtex/fil DTY weft yarn indicated higher thermal conductivity results compared to those with 400 dtex/fil AJT weft yarn. It is also observed that thermal conductivity results increased as the incorporated amount of TiO_2 (%) increased for the samples with round cross sectional fibres however there is an opposite situation for the samples with hollow cross sectional shape fibres. According to figure 1, maximum thermal conductivity was obtained from samples made of 334/192 denier/fil weft yarns having round cross sectional fibre with 1.8 TiO_2 (%) amount while lowest value was observed among the samples produced from 400/192 denier/fil weft yarns having round cross sectional fibre with 0.3 TiO_2 (%) additive. Thermal diffusivity results are also displayed in figure 2. Maximum result was obtained from C1 coded samples produced from 334/192 denier/fil round weft yarns with 0.3 TiO_2 % amount. On the other hand C7 coded samples of 400/192 denier/fil weft yarns having round fibres with 0.3 TiO_2 % provided the minimum result.

Thermal absorptivity results of samples from 400 denier/fil weft yarns having round cross sectional fibres revealed slighlty higher values compared to other samples (figure 3). It is prominently clear that thermal absorptivity of samples produced from 334/192 denier/fil weft yarn with round fibre cross sectional shape increased as the incorporated amount of TiO_2 (%) increased . However there was a fluctuating trend for the thermal absorptivity results among the other fabric counterparts. Maximum thermal absorptivity was obtained from C11 coded samples produced from 400/192 denier/fil AJT weft yarn having round cross sectional fibres while minimum value was obtained from C1 coded samples produced from 334/192 denier/fil DTY weft yarn having round cross sectional fibres. Within the scope of this result, it may be observed that the thermal absorptivity values of drapery fabrics range from 170 to 190 ($Ws^{1/2}/m^2$ K). Fabric thickness results of samples with 334/192 denier/fil DTY weft yarn having round cross sectional fibre revealed higher values compared to rest of the samples (figure 4). There is not a prominent trend for the fabric thickness results of samples with regard to incorporated amount of TiO_2 (%). Maximum fabric thicknes was obtained from samples of 334/192 denier/fil DTY weft yarn having round cross sectional fibre with 1.2 TiO_2 (%) whereas minimum result was found among the samples from 400/192 denier/fil AJT weft yarn having round cross sectional fibre with 0.3 TiO_2 (%). Thermal resistance results of the polyester drapery samples are revealed in figure 5. Drapery samples produced from 334/192 denier/fil DYT weft yarns having round cross sectional fibres with 0.3 and 1.2 TiO_2 (%) amount have slighlty higher thermal resistance compared to other samples. It is also observed that increment of incorporated TiO_2 (%) resulted with the decrement of thermal resistance among the samples with 334/192 denier/fil DTY weft yarns . According to figure 5 , maximum thermal resistance was obtained from C2 coded samples with 334/192 denier/fil DTY weft yarms with round cross sectional fibre at 1.2 TiO_2 (%) while minimum value was found among the C11 coded samples with 400/192 denier/fil AJT weft yarns with hollow cross sectional fibre at 1.2 TiO_2 (%) . Figure 6 indicates the peak heat flow density (q) 400/192 denier/fil AJT weft yarns with round cross-sectional fiber at 1.2 TiO_2 (%) indicated the maximum value while samples of 334/192 DTY weft yarn with round cross-sectional fiber at 0.3 TiO_2 revealed the minimum value. Among the samples of 334/192 denier/fil weft yarns with round cross sectional fiber shape, there is an increment trend for the q values as the incorporated amount of TiO_2 (%) increased. But there is not a certain trend for the q results regarding to amount of TiO_2 (%) in the remaining sample groups.

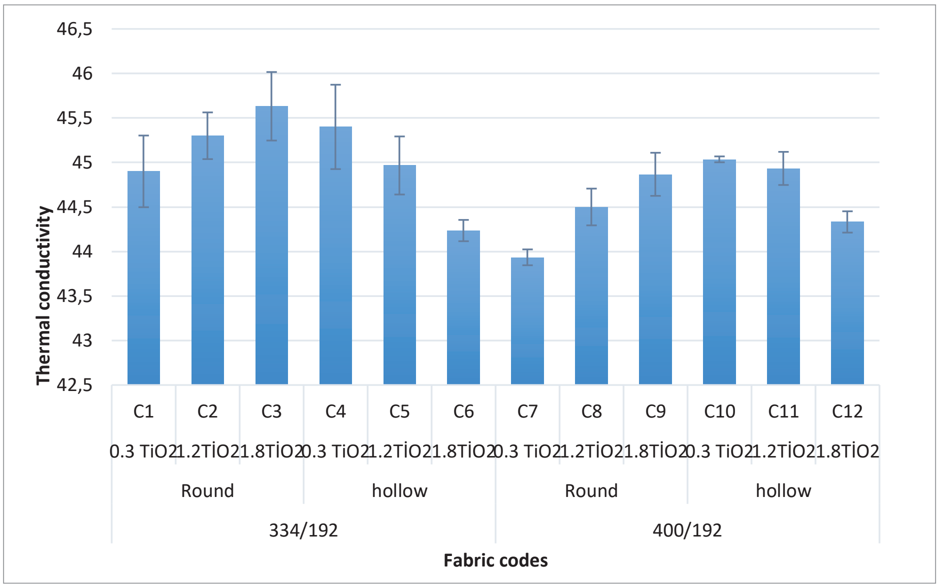

Figure 1: Thermal conductivity

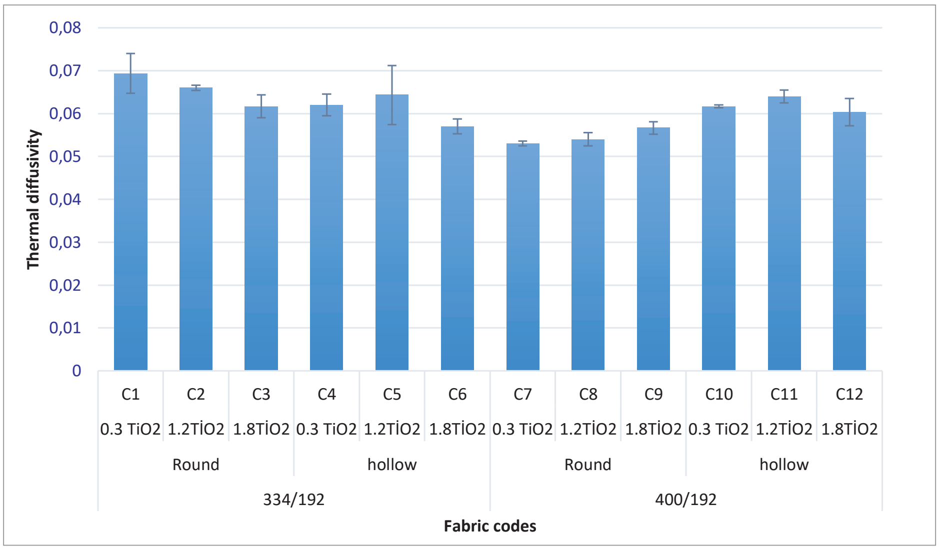

Figure 2: Thermal Diffusivity

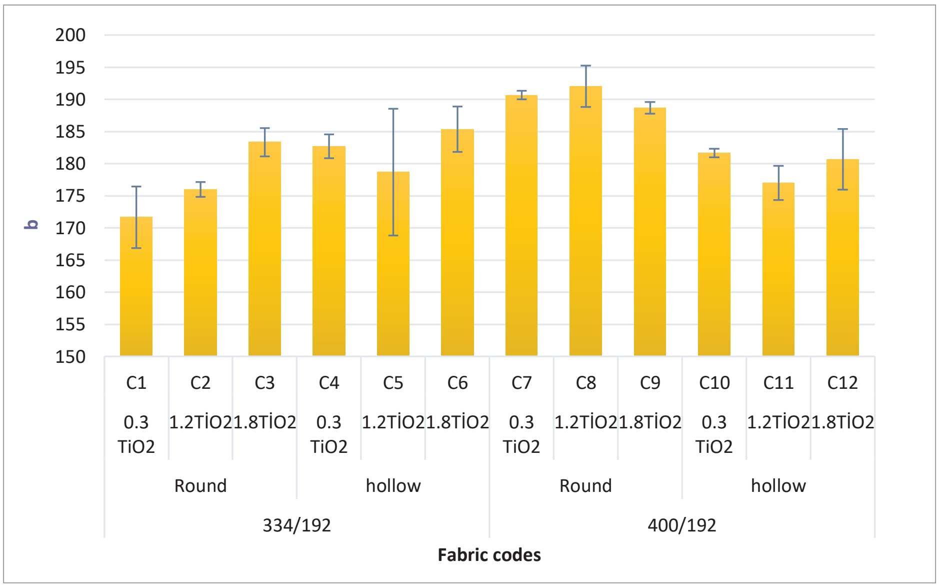

Figure 3: Thermal absorptivity

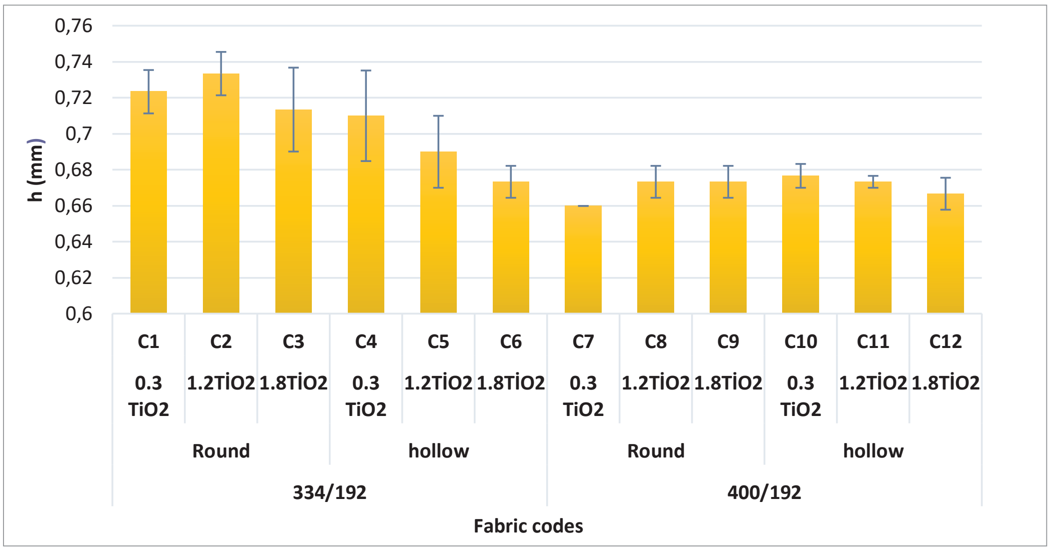

Figure 4: Fabric thickness

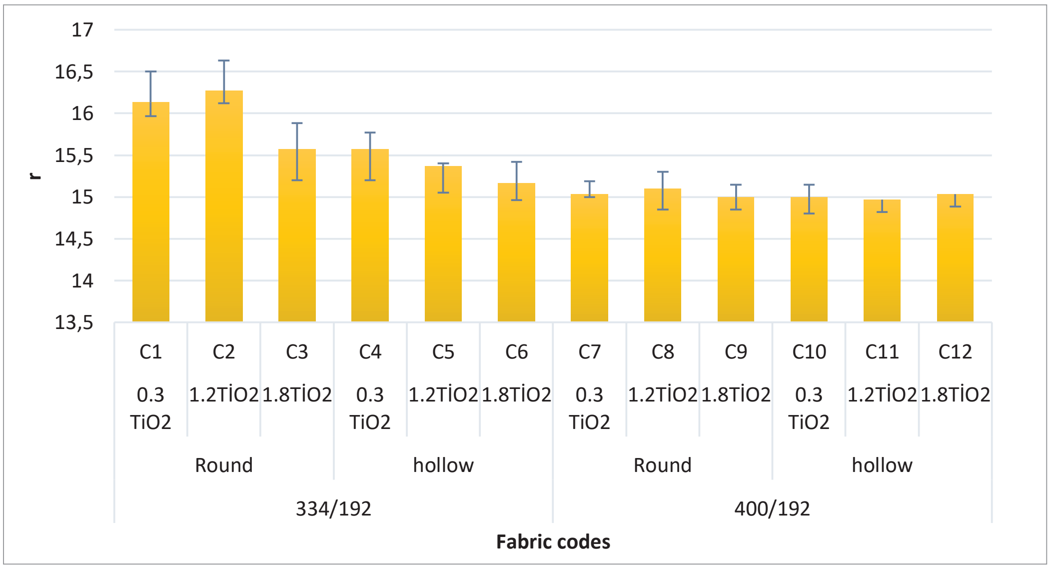

Figure 5: Thermal resistance

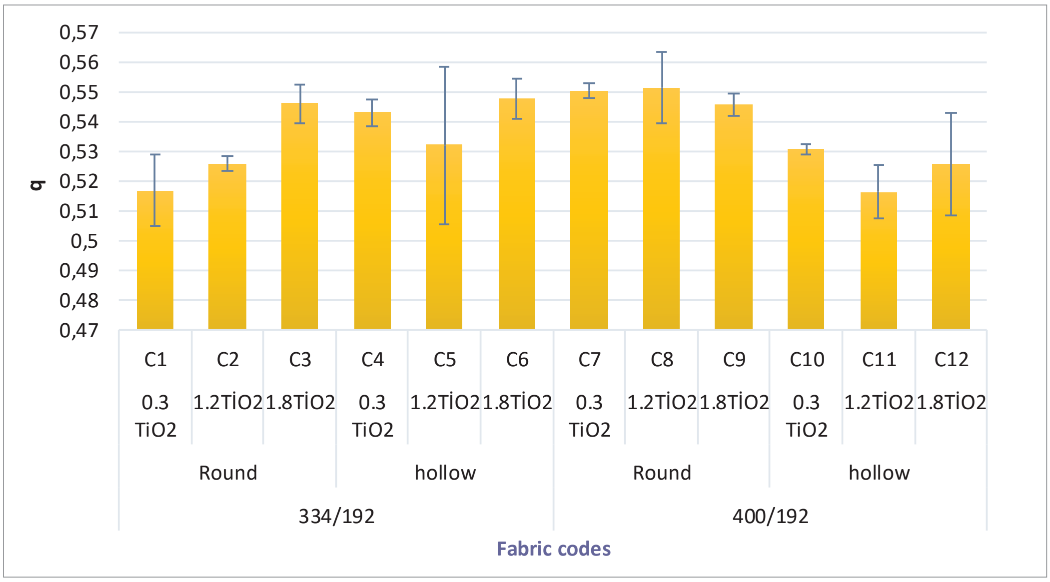

Figure 6: peak heat flow density (W.m^2)

Additionally, Three-Way ANOVA was utilized in order to investigate the effect of weft yarn type, fibre cross sectional shape and incorporated TiO$_2$ (%) additive amount on thermal properties of the produced drapery fabrics at significant ratio of 0.05 (table 5). Beside ANOVA results, Student-Newman-Keuls (SNK) was also performed for the comparison of means of thermal properties (table 6). According to ANOVA table, thermal conductivity was significantly influenced from weft yarn type, from the interaction of TiO$_2$ * fibre cross sectional shape, interaction of TiO$_2$ * weft yarn type and from the interaction of fibre cross sectional shape*weft yarn type. Thermal diffusivity and thermal absorptivity results were significantly influenced from the weft yarn type and from the interaction of fiber cross sectional shape and weft yarn type parameters at significance level of 0.05. Thermal resistance was significantly influenced from fiber cross sectional shape and weft yarn type and from the interaction of fiber cross sectional shape and weft yarn type parameters at significance level of 0.05. Fabric thickness was influenced from weft yarn type, and the interaction of weft yarn type and fiber cross sectional shape parameters. Peak heat flow density ratio was only influenced from the interaction of fiber cross sectional shape and weft yarn type parameters (Table 5). SNK test results could only be achieved for the effect of TiO$_2$ amount (%) since the other parameters consist of two levels. SNK results revealed that drapery samples made of polyester weft yarns with different TiO$_2$ amount (%) possessed statistically different thermal properties. The provided means under related thermal property were found under the same subset at significance level of 0.05 (table 6).

Table 5: ANOVA results for thermal properties

Main source	**λ (W.m^{-1}.K^{-1}).1^{0}-3**	**α (m^2.s^{-1}).10^{-6}**	**b (W.s$^{1/2}$)/m^2.**K	**r (m^2. K)/W.1$^{0-3}$**	**h (mm)**	**q (W/m^2).10^3**
TİO$_2$ (%)	0.70	0.28	0.40	0.25	0.44	0.46
Fiber cross sectional shape	0.80	0.40	0.23	**0.01***	0.07	**0.30**
Weft yarn type	**0.00***	**0.00***	**0.02***	**0.00***	**0.00***	0.08
TiO$_2$ * Fiber cross sectional shape	**0.00***	0.51	0.44	0.58	0.36	0.52
TiO$_2$ * weft yarn type	**0.03**	0.12	0.10	0.10	0.06	0.07
Fiber cross sectional shape*weft yarn type	**0.02***	**0.00***	**0.00***	**0.03***	**0.03***	**0.01***
TiO$_2$ * Fiber cross sectional shape * weft yarn type	0.94	0.65	0.64	0.87	0.93	0.72

* significantly important

3.2. Air permeability

Air permeability results are displayed in figure 7. According to figure 7: there is a general decrement as the amount of TiO$_2$ ratio (%) increased within each group except for those samples with 400/192 denier/fil AJT weft yarns with round fibres. It is observed that samples with 334/192 denier/fil DTY weft yarn have higher air permeability results compared to those with 400/192 denier/fil AJT weft yarn. This may be explained with the lower contact area of finer yarns which allows air to pass through freely and easily among the fabric. Additionally, three-way ANOVA test was conducted to investigate the effect of fibre cross sectional shape, amount of TiO$_2$ (%) and the weft yarn type on air permeability results of samples (table 7). According to ANOVA results, all three main factors and the interactions of these main sources except the interaction of fibre cross sectional type, amount of

Table 6: SNK results for thermal properties

Parameter: **TiO$_2$**	**λ** **$(W.m^{-1}.K^{-1}).10^{-3}$**	**α** **$(m^2.s^{-1}).10^{-6}$**	**b** **$(W.s^{1/2})/m^2.K$**	**r** **$(m^2.K)/W.10^{-3}$**	**h** **(mm)**	**q** **$(W/m^2).10^3$**
0.3	44.81 a	0.06 a	181.66 a	15.43 a	0.69 a	0.53 a
1.2	44.92 a	0.06 a	180.91 a	15.42 a	0.69 a	0.53 a
1.8	44.76 a	0.05 a	184.50 a	15.19 a	0.68 a	0.54 a
Parameter: **fibre** **Cross sectional shape**	**λ** **$(W.m^{-1}.K^{-1}).10^{-3}$**	**α** **$(m^2.s^{-1}).10^{-6}$**	**b** **$(W.s^{1/2})/m^2.K$**	**r** **$(m^2.K)/W.10^{-3}$**	**h** **(mm)**	**q** **$(W/m^2).10^3$**
hollow	44.81 a	0.06 a	181.00 a	15.18 a	0.68 a	0.53 a
round	44.85 b	0.06 a	183.72 b	15.51 b	0.69 b	0.53 a
Parameter: **weft yarn type**	**λ** **$(W.m^{-1}.K^{-1}).10^{-3}$**	**α** **$(m^2.s^{-1}).10^{-6}$**	**b** **$(W.s^{1/2})/m^2.K$**	**r** **$(m^2.K)/W.10-3$** **r** **$(m^2.K)/W.10^{-3}$**	**h (mm)**	**q** **$(W/m^2).10^3$** **q** **$(W/m^2).10^3$**
334/192 denier/fil	45.07 b	0.06 b	179.61 a	15.67 b	0.70 b	0.53 a
400/192 denier/fil	44.60 a	0.05 a	185.11 b	15.02 a	0.67 a	0.53 a

The different letters next to the counts indicate that they are significantly different from each other at a significance level of 0.05

TiO$_2$ (%) and weft yarn type were significant parameters on the air permeability properties of the samples at significance level of 0.05. SNK results (table 8) also indicated that samples of yarns produced with different TiO$_2$ (%) amount possessed different air permeability results. Regarding to amount of TiO$_2$ (%) in the yarns of the samples, minimum air permeability was obtained from the samples with the amount of 1.8 TiO$_2$ (%) additive while the highest air permeability was obtained from the samples of yarns with the amount of 0.3 TiO$_2$ (%) additive.

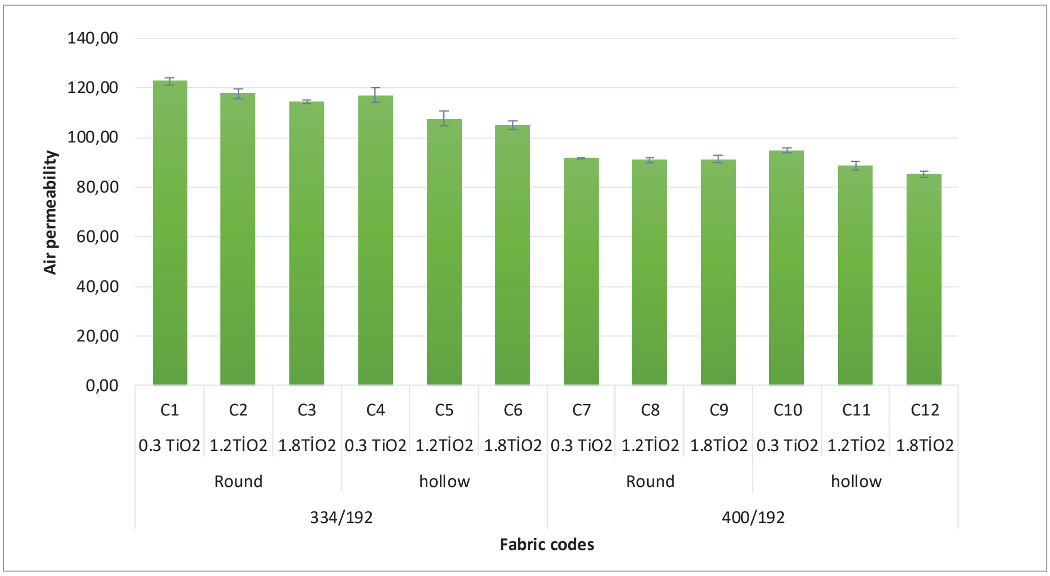

Figure 7: Air permeability

Table 7: ANOVA results for air permeability

Main source	Air permeability
TİO$_2$ (%)	**0.00***
Fiber cross sectional shape	**0.00***
Weft yarn type	**0.00***
TiO$_2$ * Fiber cross sectional shape	**0.04**
TiO$_2$ * weft yarn type	**0.00***
Fiber cross sectional shape*weft yarn type	**0.00***
TiO$_2$ * Fiber cross sectional shape * weft yarn type	0.31

* significantly important

Table 8: SNK results for air permeability

Parameter: TiO$_2$	Air permeability
0.3	106.51 c
1.2	102.36 b
1.8	99.58 a
Parameter: fibre Cross sectional shape	**Air permeability**
hollow	100.52 b
round	105.12 a
Parameter: weft yarn type	**Air permeability**
334/192 denier/fil DTY	114.43 b
400/192 denier/fil AJT	91.20 a

The different letters next to the counts indicate that they are significantly different from each other at a significance level of 0.05

3.3. Relative Water vapor Permeability (RWP), Absolute Water vapor Permeability (AWP)

Water vapor permeability results were evaluated in terms of relative water vapor permeability (RWP) and absolute water vapor permeability (AWP) which were obtained from Permetest device. Figure 8 indicates the relative water vapor permeability results of the drapery samples. Maximum relative water vapor permeability value was obtained from samples with 334/192 denier/fil DTY weft yarn with round cross sectional fibre where incorporated TİO$_2$ (%) amount was 1.8 . On the other hand, minimum relative water vapor permeability was found among the samples with 400/192 denier/fil weft yarn count with hollow cross sectional fibre where incorporated TİO$_2$ amount was 1.8 (%). There is not a prominent trend for RWP results regarding to fibre cross sectional shape of drapery samples. When the absolute water vapour permeability (figure 9) is considered, samples with 400/192 denier/fil weft yarn made of hollow fibres with 1.8 % incorporated TiO$_2$ additive revealed the maximum absolute water vapor permeability (Pa.m^2/ w) while samples with 400/192 denier/fil weft yarn count made of round fibres with 1.2 % incorporated TiO$_2$ additive revealed the minimum absolute water vapor permeability. There is not a prominent difference between the absolute water vapor permeability results of samples regarding to fibre cross sectional shape or weft yarn type of drapery samples.

Three-way ANOVA was conducted to investigate the effect of fibre cross sectional shape, incorporated TiO$_2$ amount (%) and the weft yarn type parameters on the relative (%) and absolute water vapor permeability (Pa.m^2/ w) values of the samples. According to ANOVA table (table 9), fibre cross sectional shape, weft yarn type parameters were significant factors on RWP, AWP values at significance level of 0.05. TiO$_2$ (%) amount was a significant factor on AWP results. Interaction of TiO$_2$ and fibre cross sectional shape parameter was a significant factor on RWP values at significance level of 0.05. Interaction of TiO$_2$ and weft yarn type parameter, interaction of fibre cross sectional shape and weft yarn type and the interaction of TiO$_2$, fibre cross sectional shape and weft yarn type parameters were significant factors on AWP results. SNK results also indicated that samples with different TiO$_2$ amount (%) possessed different RWP and AWP results at significance level of 0.05 (table 10). Considering RWP results, samples produced from weft yarns with 0.3 TiO$_2$ (%), 1.2 TiO2 (%) and 1.8 TİO$_2$ (%) amount were observed under the same subset at significance level of 0.05. As AWP results are evaluated, samples produced from weft yarns with 0.3 and 1.8 TİO$_2$ (%) revealed higher AWP results compared to those with 1.2 TİO$_2$ (%).

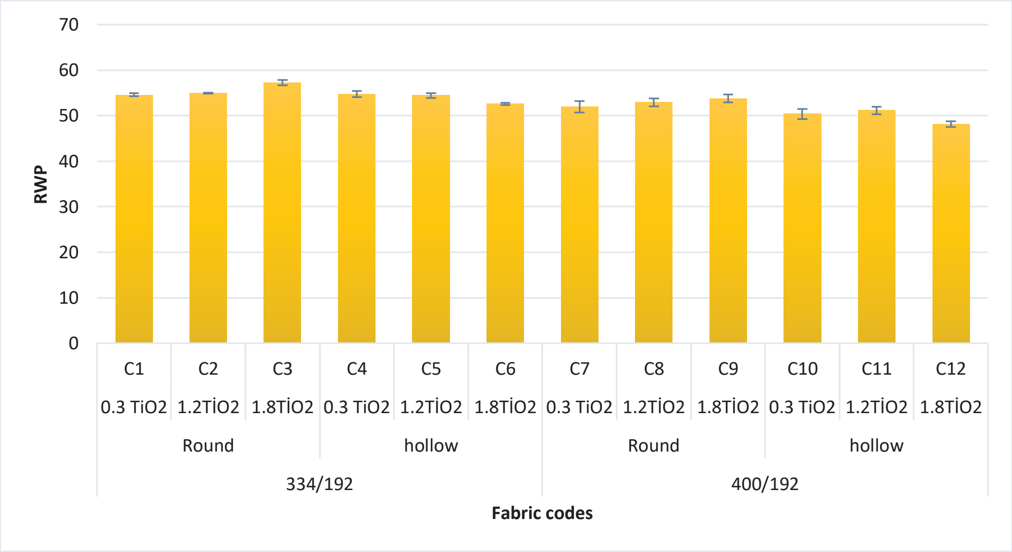

Figure 8: Relative water vapor permeability (%)

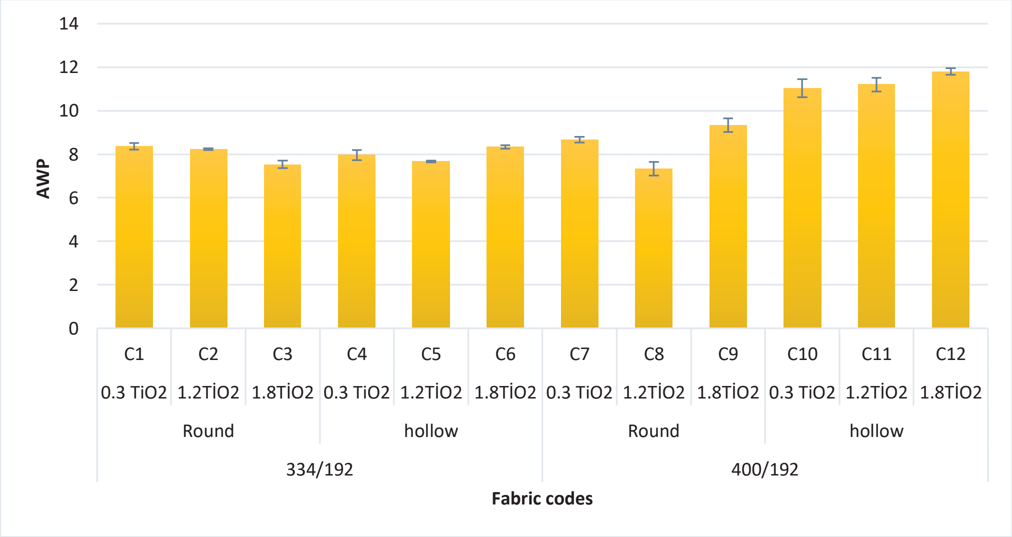

Figure 9: Absolute water vapour permeability (Pa.m^2.w^{-1})

Table 9: ANOVA results for RWP and AWP

Main source	RWP	AWP
TİO$_2$ (%)	0.65	**0.00***
Fiber cross sectional shape	**0.00***	**0.00***
Weft yarn type	**0.00***	**0.00***
TiO$_2$ * Fiber cross sectional shape	**0.01***	0.08
TiO$_2$ * weft yarn type	0.47	**0.00***
Fiber cross sectional shape*weft yarn type	0.14	**0.00***
TiO$_2$ * Fiber cross sectional shape * weft yarn type	0.94	**0.00***

* significantly important

4. CONCLUSION

This study has been conducted to reveal the effect of fibre cross sectional shape, amount of incorporated TiO$_2$ (%) and weft yarn type on thermal, air permeability and water vapor permeability properties of drapery fabrics. According to bar graphs and ANOVA analyses, , it is revealed that samples with 334/192 denier DTY (draw textured) weft yarn generally indicated higher thermal conductivity values compared to those with 400 denier/192 AJT (Air jet textured) weft yarns. Thermal conductivity was mainly influenced from weft yarn type.

Regarding to thermal absorptivity, it may be observed that samples of 400/192 denier/fil AJT weft yarn with round cross sectional shape generally showed higher thermal absorptivity values compared

Table 10: SNK results for relative and absolute water vapor permeability

Parameter: TiO_2	**RWP**	**AWP**
0.3	52.91 a	9.0 b
1.2	53.35 a	8.60 a
1.8	52.94 a	9.25 b
Parameter: fibre Cross sectional shape	**RWP**	**AWP**
hollow	51.91 a	9.66 b
round	54.23 b	8.24 a
Parameter: weft yarn type	**RWP**	**AWP**
334/192 denier/fil	54.76 b	8.01 a
400/192 denier/fil	51.38 a	9.89 b

The different letters next to the counts indicate that they are significantly different from each other at a significance level of 0. 05

to others. Thermal absorptivity results were influenced significantly from the weft yarn type and from the interaction of fiber cross sectional shape and weft yarn type parameters at significance level of 0.05. Thermal resistance was significantly influenced from fibre cross sectional shape and weft yarn type and from the interaction of fiber cross sectional shape and weft yarn type parameters at significance level of 0.05. Weft yarn type parameter had a significant effect on fabric thickness at significance level of 0.05. Another remarkable result is fabric thickness and thermal resistance results are compatible with each other. Thermal diffusivity results were significantly influenced from the weft yarn type and from the interaction of fiber cross sectional shape and weft yarn type parameters at significance level of 0.05.

Considering air permeability results; All three main factors were influential parameters on the air permeability properties of the samples at significance level of 0.05. Bar graphs and statistical results revealed that increment of incorporated TiO_2 amount (%) led to decrement of air permeability. It may be also anticipated that texturing type of weft yarns has also considerable effect on the air permeability of drapery samples. Drapery samples produced from 400/192 denier/fil AJT weft yarns indicated lower air permeability and relative water vapor permeability (%) results compared to those fabrics with 334/192 denier/fil DTY weft yarns. There is not a prominent trend for relative and absolute water vapor permeability results regarding to cross sectional shape of the fibres of drapery samples. ANOVA tests indicated that fibre cross sectional shape, weft yarn type parameters were significant factors on RWP, AWP values at significance level of 0.05.

As a general evaluation, weft yarn properties including the linear density, the texturing method, incorporated TiO_2 amount (%) during spinning process, its constituting fiber cross sectional shapes were generally influential factors on thermal comfort properties such as thermal, air permeability and water vapor permeability. Hence regarding to final aim of the drapery samples, it is recommended to develop new drapery fabric designs made of synthetic yarns produced with varying production parameters such as different fiber cross sectional area , incorporated amount of additive materials, texturing type ..etc in order to increase their commercial usage.

ACKNOWLEDGEMENT

The authors would like to thank to ULUDAĞ UNIVERSITY for the test devices placed in the laboratory of_ Textile Engineering Department and would like to thank to VANELLI TEXTILE and POLYTEKS A.Ş (BURSA, TURKEY) for their contribution during the samples production.

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Primljeno/Received on: 01.05.2023.
Revidirano/ Revised on: 02.06.2023.
Prihvaćeno/Accepted on: 02.06.2023.