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To cite this article: E K Çeven and G K Günaydın 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **254** 052003

IOP Conf. Series: Materials Science and Engineering **254** (2017) 052003 doi:10.1088/1757-899X/254/5/052003

Effect of structural parameters on burning behavior of polyester fabrics having flame retardancy property

E K Çeven[1] and G K Günaydın[2]
[1]Uludag University, Faculty of Engineering, Textile Engineering Department, Görükle Campus, 16059, Nilüfer, Bursa, Turkey
[2]Pamukkale University, Buldan Vocational School, 20400, Buldan, Denizli, Turkey

Email: ggunaydin@pau.edu.tr

Abstract The aim of this study is filling the gap in the literature about investigating the effect of yarn and fabric structural parameters on burning behavior of polyester fabrics. According to the experimental design three different fabric types, three different weft densities and two different weave types were selected and a total of eighteen different polyester drapery fabrics were produced. All statistical procedures were conducted using the SPSS Statistical software package. The results of the Analysis of Variance (ANOVA) tests indicated that; there were statistically significant (5% significance level) differences between the mass loss ratios (%) in weft and mass loss ratios (%) in warp direction of different fabrics calculated after the flammability test. The Student-Newman-Keuls (SNK) results for mass loss ratios (%) both in weft and warp directions revealed that the mass loss ratios (%) of fabrics containing Trevira CS type polyester were lower than the mass loss ratios of polyester fabrics subjected to washing treatment and flame retardancy treatment.

1. Introduction

Fire-retardant fabrics are textiles that are naturally more resistant to fire than others through chemical treatment or manufactured fireproof fibers. Four approaches can be considered to reduce the flammability of textiles: First is, to use inherently flame retardant textiles comprising the so called high performance fibres (e.g., polyoxazoles, polyether etherketone, polymides, carbon, asbestos, glass, polibenzimidazol, kyrol, polifenilensulfur and aramides) [1,2]. Second is changing the structures of fibers by copolymerization (chlorine content) and chemical modification. The flame retardant monomer takes part at the chain structure of the polymer. The examples are: FR polyester, FR polyamide, FR wool [3]. One of the classic solutions to flame retard polyester is to incorporate a comonomeric phosphinic acid unit into the PET polymeric chain. Third is to incorporate flame retardants into synthetic polymer before spinning process. These chemicals are organic phosphor, antimon oxide, organic halogen compounds, inorganic magnesium hydroxide and inorganic boric acid. The last is surface treatment of fabric with fire retardant chemicals. This method is preferred especially for the upholstery fabrics [4-5]. Polyester, mainly poly(ethylene terephthalate) has been widely used for textile fiber, technical fiber, film and bottles because of its good mechanical properties and thermal stability and its low production cost. As interest on the danger of fire, the demand for flame retardant (FR) polyesters has been strong [6]. There are some studies concerning the investigation and comparison of fire retardant polyester fabrics treated with different flame retardancy methods (such as surface treatment, using yarns having the flame retardant property…etc) [7-10]. Yu et al. (2015) made an investigation about the flame retardancy and conductive properties of polyester

IOP Conf. Series: Materials Science and Engineering **254** (2017) 052003 doi:10.1088/1757-899X/254/5/052003

fabrics coated with polyaniline. The performance of flame retardancy and conductivity of polyester fabrics were studied by Limiting Oxygen Index (LOI) and cyclic voltammetry measurements [7]. Carosio et al. applied a novel method to improve flame retardant properties of textile fabric using multilayered thin films. PET fabrics were coated with silica nanoparticles using layer-by-layer assembly [8]. Yang et al. have evaluated and analyzed the performance of flame retardant textiles They applied MCC to evaluate the flammability of different textile fabrics including cotton, rayon, cellulose acetate, silk, nylon, polyester, polypropylene, acrylic fibers, Nomex and Kevlar [9]. Kotresh et al. (2006) made an investigation about the burning behavior of commercial flame retardant (FR) polyester curtain fabric samples with varying weights in the range of 300–550 g/m^2 is by using cone calorimeter [10]. As a result of the literature survey, it was observed that there are limited experimental studies about the comparison of burning behavior of polyester fabrics treated with different flame retardancy methods. This study also aims at filling the gap in the literature about the studies on the fire resistance performance of polyester fabrics with TREVIRA CS yarn by investigating the flammability degree in terms of mass loss ratios (%) of the fabrics.

2. Materials and Methods

In the study, a total of 18 different polyester drapery fabrics varying with fabric types, weave types and weft densities were woven on Dornier Staubli Jacquard Machine. Table 1 displays the experimental design of the study.

Table 1. Experimental Design

Fabric Codes	Property
WT36S	PES, washing treatment, 36 weft density, weft satin
WT36R	PES, washing treatment, 36 weft density, filling rib
WT40S	PES, washing treatment, 40 weft density, weft satin
WT40R	PES, washing treatment, 40 weft density, filling rib
WT44S	PES, washing treatment, 44 weft density, weft satin
WT44R	PES, washing treatment, 44 weft density, filling rib
FR36S	PES, flame retardancy treatment, 36 weft density, weft satin
FR36R	PES, flame retardancy treatment, 36 weft density, filling rib
FR40S	PES, flame retardancy treatment, 40 weft density, weft satin
FR40R	PES, flame retardancy treatment, 40 weft density, filling rib
FR44S	PES, flame retardancy treatment, 44 weft density, weft satin
FR44R	PES, flame retardancy treatment, 44 weft density, filling rib
TR36S	PES, Trevira CS, 36 weft density, weft satin
TR36R	PES, Trevira CS, 36 weft density, filling rib
TR40S	PES, Trevira CS, 40 weft density, weft satin
TR40R	PES, Trevira CS, 40 weft density, filling rib
TR44S	PES, Trevira CS, 44 weft density, weft satin
TR44R	PES, Trevira CS, 44 weft density, filling rib

The coding of the fabrics according to structural parameters is given by:

ABC : (A) fabric type (B) weft density (C) weave type

for A : WT stands for polyester fabric subjected to washing treatment
FR stands for polyester fabric subjected to flame retardancy treatment

TR stands for polyester fabric woven with Trevira CS weft yarn

for B:

36 stands for 36 wefts/cm
40 stands for 40 wefts/cm
44 stands for 44 wefts/cm

for C:

S stands for 1/10 weft satin Z (3)
R stands for 5/5 filling rib

For example, TR40S means that the fabric having a weave type of for 1/10 weft satin Z (3) is woven with Trevira CS weft yarn at 40 wefts/cm. The 75 denier /36 fil, 800 tpm (Z direction) Fdy Trilobal Bright Flat polyester was used as the warp yarn and warp density was selected as 60 warps/cm for all group of fabrics. In WT and FR coded fabrics, 30/2 600 tpm (S direction) staple ring polyester yarn was selected as weft yarns. In FR coded fabrics, thermoplastic polymer dispersion called Afflamit TSP containing phosphorus and nitrogen compounds was applied for the flame retardancy treatment. The TR Coded fabrics were produced from the same warp yarns with the other groups but with a different weft yarn of Trevira CS polyester which is a flame retardant yarn. A testing device of NFP 92-503 was used in order to measure the mass loss ratios (%) of the fabrics in the weft and warp direction for the flammability test. The fabric samples were inclined at 30^0 to the horizontal and were subjected to a radiant heat flux for 5 minutes and flaming ignition source was applied to the heated fabrics. Figure 1 displays the NFP 92-503 Electric Burner Testing device [11]. All statistical procedures were conducted using the SPSS 23.0 statistical software package. In the study completely randomized single factor (fabric type) analysis of variance (ANOVA) and Student-Newman-Keuls (SNK) tests were used. The value of significance level (α) selected for all statistical tests in the study is 0.05. The treatment levels were marked in accordance with the mean values, and any levels marked by different letter (a, b, c) showed that they were significantly different.

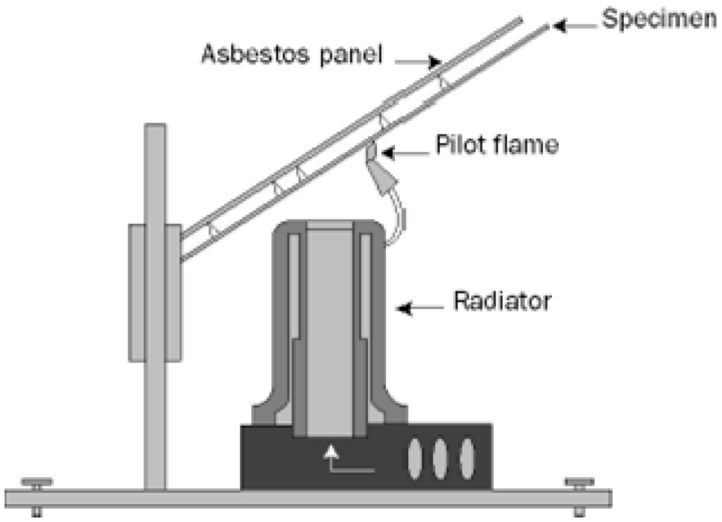

Figure 1. NFP 92-503 Electric Burner Test.

3. Results and Discussion

The mass loss ratios (%) of the fabrics in weft and warp direction in the flammability test were shown in fig.2 and fig.3 respectively. It was observed that the minimum mass loss ratio (%) in weft direction was obtained as 0.15 from the TR44R coded fabrics and the maximum mass loss ratio (%) in weft direction was obtained as 4.36 from the WT40S coded fabric; while the minimum mass loss ratio (%) in warp direction was obtained as 0.40 from the TR44S and TR44R coded fabrics and the maximum mass loss ratio (%) in warp direction was obtained as 2.90 from the WT36S coded fabric.

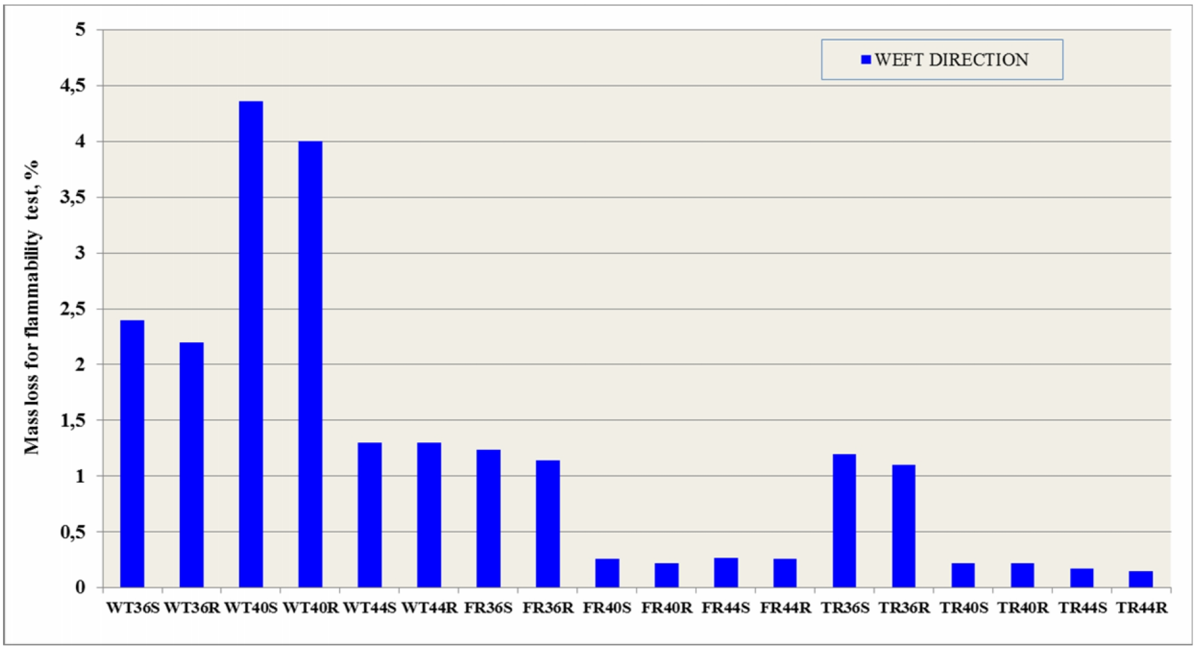

Figure 2. The mass loss ratios (%) of the fabrics in weft direction in the flammability test.

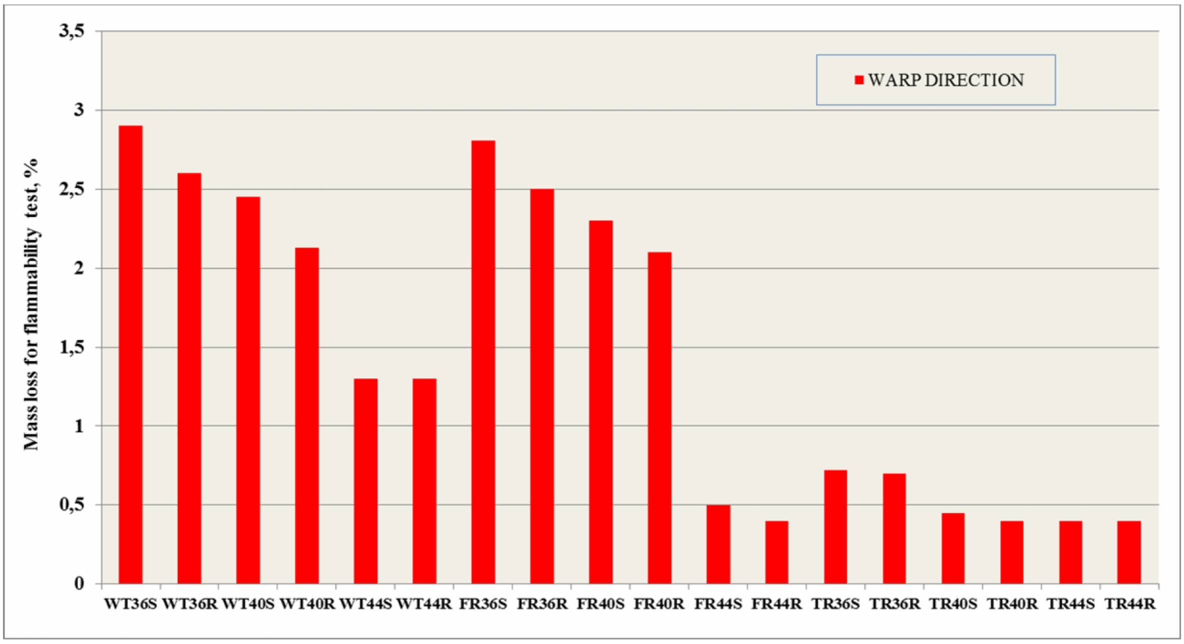

Figure 3. The mass loss ratios (%) of the fabrics in warp direction in the flammability test.

The results of the of ANOVA test indicated that at all weft densities, the fabric type had significant effect on the mass loss ratios (%) after burning for warp and weft directions. In another explanation, for all weft densities, there were statistically significant (5% significance level) differences between the mass loss ratios (%) of different fabric types in the warp and weft direction. The SNK results at Table 2 revealed that the mass loss ratio (%) of TR and FR coded fabrics were statistically in the same level and were lower than the mass loss ratio (%) value of WT coded fabrics at the weft density of 36 and 40. The minimum mass loss ratio (%) in the weft direction for weft density of 44 was obtained as 0.17 % from TR coded fabric and the maximum mass loss ratio (%) was obtained as 1.3 % from WT coded fabric.

Table 2. SNK Test Results for Mass Loss Ratios (%) in Weft Direction in Flammability Test for 1/10 Weft Satin Z (3)

Fabric Types	Weft Density for 1/10 weft satin Z (3)		
	36	**40**	**44**
TR	1.2 a	0.22 a	0.17 a
FR	1.24a	0.26 a	0.27 b
WT	2.40 b	4.36b	1.30 c

The SNK results at Table 3 revealed that the mass loss ratio (%) of TR and FR coded fabrics were statistically in the same level and were lower than the mass loss ratio (%) value of WT coded fabrics at the weft density of 36 and 40. The minimum mass loss ratio (%) in the weft direction for weft density of 44 was obtained as 0.15 % from TR coded fabric and the maximum mass loss ratio (%) was obtained as 1.3 % from WT coded fabric and the values were statistically different for all the fabric types. The SNK results for the warp direction at Table 4 revealed that the mass loss ratios (%) of TR coded fabrics were lower than the mass loss ratios of FR and WT coded fabrics at weft densities of 36, 40 and 44. At the weft density of 36, the maximum mass loss ratio was obtained as 2.9 % from the WT coded fabrics and there was statistically significant difference between the mass loss ratios of all types of fabrics. At the weft density of 40, the mass loss ratio of FR and WT coded fabrics were statistically in the same level and statistically higher than TR coded fabric. At the weft density of 44, the mass loss ratio of TR and FR coded fabrics were statistically in the same level and lower than WT coded fabric.

Table 3. SNK Test Results for Mass Loss Ratios (%) in Weft Direction in Flammability Test for 5/5 Filling Rib

Fabric Types	Weft Density for 5/5 filling rib		
	36	**40**	**44**
TR	1.10 a	0.22 a	0.15 a
FR	1.14 a	0.22 a	0.26 b
WT	2.20 b	4.00 b	1.30 c

Table 4. SNK Test Results for Mass Loss Ratios (%) in Warp Direction in Flammability Test for 1/10 Weft Satin Z (3)

Fabric Types	Weft Density for 1/10 weft satin Z (3)		
	36	**40**	**44**
TR	0.72 a	0.45 a	0.40 a
FR	2.81 b	2.30 b	0.50 a
WT	2.90 c	2.45 b	1.30 b

The SNK results for the warp direction at Table 5 revealed that the mass loss ratios (%) of TR coded fabrics were lower than the mass loss ratios of FR and WT coded fabrics at weft densities of 36, 40 and 44. At the weft density of 36, the minimum mass loss ratio was obtained as 0.7 % from the TR coded fabrics and there was statistically significant difference between the mass loss ratios of all types of fabrics. At the weft density of 40, the mass loss ratio of TR coded fabric was statistically lower than FR and WT coded fabrics which were statistically in the same level. At the weft density of 44, the mass loss ratio of TR and FR coded fabrics were statistically in the same level and lower than WT coded fabric. It can be concluded from the results that weave type did not affect the tendency of the fabric types against burning test.

Table 5. SNK Test Results for Mass Loss Ratios (%) in Warp Direction in Flammability Test for 5/5 Filling Rib

Fabric Types	Weft Density for 5/5 filling rib		
	36	**40**	**44**
TR	0.70 a	0.40 a	0.40 a
FR	2.50 b	2.10 b	0.40 a
WT	2.60 c	2.13 b	1.30 b

4. Conclusion
After evaluating the test results, it should be emphasized that the mass loss ratios (%) of the fabrics with Trevira CS polyester weft yarn had the lowest value which indicates that Trevira CS polyester "a special modificated fiber" provide a higher flammable property to the fabric than the surface treatment of fabric with fire retardant chemicals. This study is thought to be useful for the new studies concerning the effect of fire retardancy methods and fabric structures to the other physical properties of fabrics like tear resistance and flexural rigidity.

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