〔東京家政大学研究紀要　第31集 (2). p. 49～56, 1991〕

Flammability of Cotton and Polyester (PET) Union Cloth

Reiko ISHIKUBO

(Received September 29, 1990)

Introduction

The particular combination of polyester/cotton blend represents a more flammable situation than that which arises when each fiber type is used separately owing to the well-known "scaffold effect". The comprehension of their interaction with polyester, the mechanistic role of flame retardants in the pyrolysis and combustion of polyester, is still very small despite several studies [1~4] on the subject. In previous papers[5~9], the flammability of the blended yarns and fabrics was represented by the series and parallel model of the burning resistance of each yarn and fabric with the mixing parameter X, that has been investigated.

In this paper, the flame-retarded effects of the yarn finished with the flame retardant (cotton finished with THPC as warps, polyester unfinished as fillings) on the flammability properties of these union cloths which were burned in both directions (the lengthwise and the crosswise) will be considered.

Experimental

MATERIALS

FABRIC PREPARATION AND FLAME RETARDANT TREATMENT. 30's polyester yarn and 30's cotton yarn treated by the soxhlet's extractor with alcohol/benzol (50/50) solution for two hours, were used. The plain fabric consisted of these yarns (polyester yarn as warp and cotton yarn as filling which was woven with the hand loom).

第2被服材料研究室，服飾美術科 *

In this case, the cotton yarn was treated with THPC flame retardant. The treatment method was as follows.

The First Bath

THPC	17g
Tetrakis (hydroxymethyl) Phosphonium Chloride	
Etanolamine	3g
Water	16ml

The Second Bath

Urea	15g
Water	45g

After mixing the first bath solution and the second bath solution at room temperature, the cotton yarn were tied up like the strings were immersed in the mixed solution (o.w.f. 1:50) for 30 min. and padded to 100% wet pick-up. The predrying lasted 45 min. at 85°C, and the curing for 4.5 min. at 140°C. The treated fabric had a weight add-on of about 37%. As the ratio of flame retardant cotton, the treated cotton/the untreated cotton with polyester union cloth were woven in the series of the following contents: 0/100, 20/80, 33/67, 40/60, 50/50, 60/40, 67/33, 80/20, 100/0, respectively. It was given in Table 2 and fabric constructions were shown in Figure 1 (A, B). Physical properties of the fabric was determined using the appropriate JIS Standard Test methods (Table 1).

TEST PROCEDURES

FLAMMABILITY MEASUREMENTS. All flammability tests were conducted at an ambient temperature (between 20°C and 27°C) and a relative humidity (between 60%RH and 70%RH) existing in the laboratory. Burning rate was measured with the 45 degree Flammability Tester and oxygen indices (OI) were determined with the

Table 1 Details of test fabrics

measurement	items	measurement values*
Fabric count	Ends/cm	18.0
	Picks/cm	18.0
Thickness	(mm)	0.468
Mass/Unit Area	(g/m^2)	170

*Hundred measurements were carried out.

Table 2 Fabric Composition

The ratio of treated cotton yarns (%)	Number of the cotton yarn	
	Treated	Untreated
0	0 count	— count
20	2	8
33	2	4
40	4	6
50	2	2
60	6	4
67	4	2
80	8	2
100	—	0

Union cloth content (%)
: cotton (Fill) : PET (Warp)
(50 : 50)
Construction : plain weave
cotton yarn : 30's, Number of turns 6.6 T/cm
Polyester yarn : 30's, Number of turns 5.4 T/cm

Oxygen Index Apparatus.

a) 45 degree Flammability Test Method: Fabric burning rate was carried out by the JIS L-1901 C method 45 degree upward burning, except that the ignitiontime was 5 sec. and the sample was ignited at the bottom. Specimens for both directions (lengthwise and crosswise) measuring 16cm in the warp direction and 8cm in the fill are shown in Figure 2. They were controlled in the room at 65%RH and 20°C for a week, after which they were

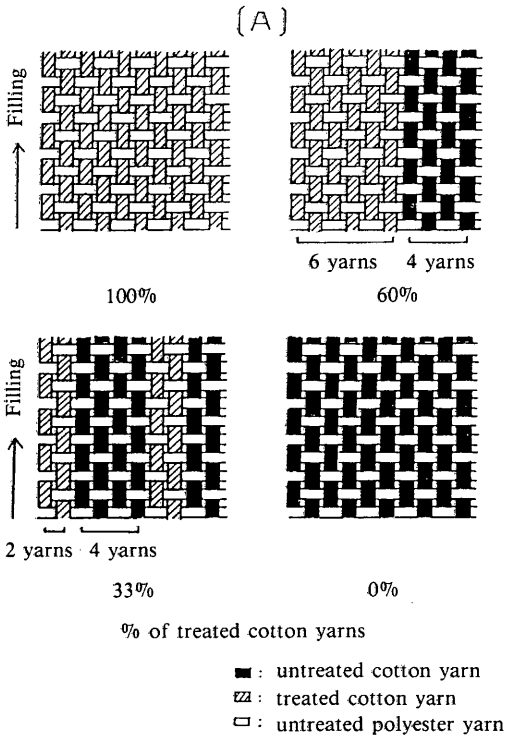


Fig. 1 (A) Diagram of the ratio of treated/untreated cotton yarn

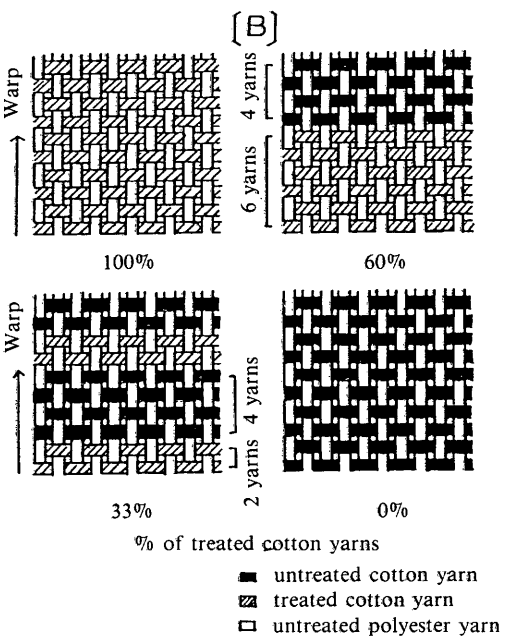


Fig. 1 (B) Diagram of the ratio of treated/untreated cotton yarn.

placed in a metal holder, then set in the test cabinet. The burning resistance expressed as the reverse of the burning rate according to the average of each of ten burning times, was used to calculate the rates. The burning was timed by starting a stop watch at the moment, the edge ignited and stopping it when the flame extinguished completely; the burning time and the burning length.

b) Limiting Oxygen Index Test method: Ten samples (13cm × 6cm) were cut from each of the various fabrics, and were controlled in the room (20°C, 65% RH) for a week. The LOI values of the samples were carried out by the procedure that was determined by the oxygen concentration in the nitrogen-oxygen atmosphere flowing through the combution chamber using Suga Oxygen Index apparatus OH-IH Type. A 12 sec. time was used for the sample burning in the normal candle-like manner after top edge ignition using a blowtorch with a 10mm length flame. Hence, the LOI is defined as the minimum concentration of oxygen in a mixture of oxygen and nitrogen, expressed as a volume percentage that will just support fabric combustion under the conditions when 5cm length of the samples were burnt with the downward burning. Thus, the Limiting Oxygen Index is given by

$$LOI = \frac{O_2}{O_2 + N_2} \times 100$$

where O_2 = Volumetric flow of Oxygen (1/min.)
N_2 = Volumetric flow of nitrogen (1/min.)

Results and Discussion

EFFECT OF THE MIXING RATIO OF FLAME RETARDANT COTTON. Figure 2 shows the effect of the mixing ratio of the THPC flame retardant cotton on burning resistance of the union cloth (PET/cotton: 50/50). The burning directions, the lengthwise direction (A) representing the cotton yarns as the warp and the crosswise direction (B) representing the fill, are shown in the Figure 2. According to the results, no large difference in the burning resistances in both directions (A and B) was observed. However, the burning resistances in the A direction were larger than that of the B direction when the flame retardant cottons made up less than 50% of the content. In the range of approximately 50%-60% flame retardant cotton content, there is no difference between the burning resistances values in either the A direction or the B direction. Burning resistance in the A direction was at a maximum with a 30% flame retardant cotton content. The A direction of the union cloth exhibited complex burning behavior as compared to the B direction. The B direction showed almost the same burning resistance values throughout the entire range from approximately 0%-70% of flame retardant cotton content. After 80% content then it's burning resistance increased.

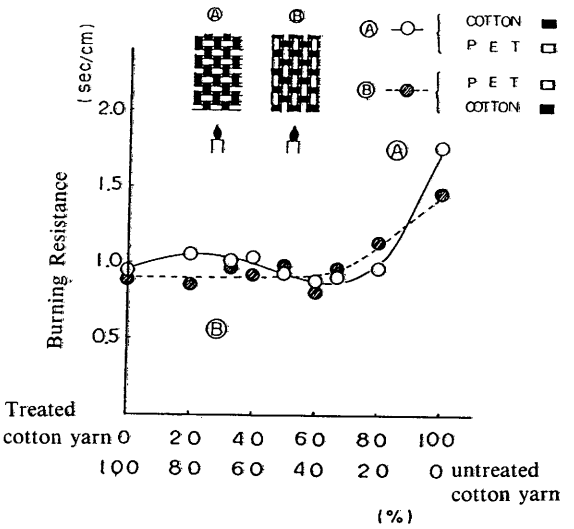


Fig. 2 Effect of the ratio of the THPC treated cotton yarn and untreated one on the burning resistance for the union cloth (cotton /polyester = 50/50)

MODEL OF BURNING RESISTANCES OF THE UNION CLOTH. On the basis of the effects demonstrated on the burning resistance of both the A and the B direction of the union cloth the following conclusions were drawn (Fig. 3). When the samples of the A direction are burnt, it can be assumed that their burning resistances will be two cases that of the parallel-series model and the parallel-parallel model. The burning resistances of the treated cotton yarns and the untreated cotton yarns as the warp can be expressed by the parallel model (equation (1)) and that of the untreated polyester yarns as the filling can be expressed by the series model (equation (2)) as follows:

the parallel model I $$Rc = \frac{2m(1-m)RtRo}{mRt + (1-m)Ro} \quad (1)$$

where m: the treated cotton/the untreated cotton ratio

Rt: the burning resistance of the treated cotton yarn

Rt = 1.33

Ro: the burning resistance of the untreated cotton yarn

Ro = 0.46

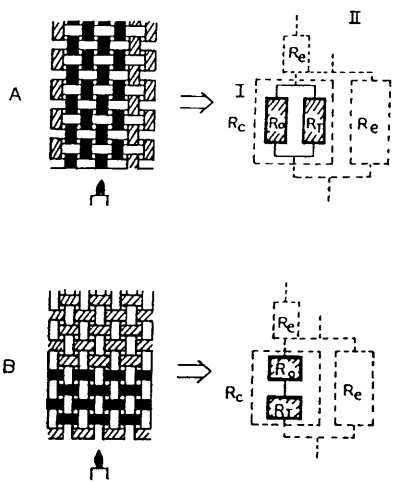
the series model II $Rp = \frac{Rc + Re}{2}$ (2)

where Rc: Rc of the equation (1), Rc = n -----

Re: the burning resistance of the untreated polyester yarn

Re = 1.06 (fill)

Re = 1.42 (mean value of warp and fill)



■ : untreated cotton yarn

▨ : treated cotton yarn

□ : untreated polyester yarn

R_c : the burning resistance of cotton yarn

R_o : the burning resistance of untreated cotton yarn

R_T : the burning resistance of treated cotton yarn

R_e : the burning resistance of untreated polyester yarn

Fig. 3 Diagram of the series and parallel model

When the samples of the B direction are burnt it can be assumed that their burning resistances will be two cases that of the series-series model and the series-parallel model. The burning resistances of the treated cotton yarns and the untreated cotton yarns as the filling can be expressed by the series model (equation (3)) and that of the untreated polyester yarns as the warp can be expressed by the parallel model (equation (4)) or the series model (equation (5)) in a similar manner as the A direction. Thus, it can be expressed by equations (3), (4), (5) as follows:

the series model I $Rc = mRt + (1-m)Ro$ (3)

where m: the treated cotton/the untreated cotton ratio

Rt: the burning resistance of the treated cotton yarn

Ro: the burning resistance of the untreated cotton yarn

the parallel model II $Rp = \frac{RcRe}{Rc + Re}$ (4)

the series model II $Rp = \frac{Rc + Re}{2}$ (5)

where Rc: Rc of the equation (3), Rc = n -----

Re: the burning resistance of the untreated polyester yarn

The results of this calculation are shown in Table 3 (A), (B) for the burning resistance of the A direction and for that of the B direction, respectively.

In the case of the burning resistances of the A direction, the values of the calculated burning resistances (Rc) according to the parallel model of equation (1) are considerbly smaller than the observed ones, so that, it appears to be substantially influenced by the burning resistance of the untreated polyester filling yarns. Therefore, when the (Re), expressed the series model, is added in equation (1), it's burning resistance (Rp) can be expressed by equation (2). When the burning resistance (Re), of the untreated polyester yarns set as the filling direction were burnt, Re = 1.06 (sec/cm), then the Rp values were slightly smaller than the observed one. Consequently, the Rp can be obtained by equation (2) using the mean value (Re) of the burning resistances of the untreated poly-

Table 3 (A) Observed and calculated values of the burning resistances for the union cloth

The ratio of treated cotton yarns (%)	The observed value (sec/cm)	Calculated by the equation (1) (sec/cm) (Rc)	Calculated by the equation (2) (sec/cm) (Rp) Re = 1.06	Calculated by the equation (2) (sec/cm) (Rp) Re = 1.42
0	0.95	—	—	—
20	1.05	0.31	0.69	0.87
33	1.01	0.36	0.71	0.89
40	1.03	0.36	0.71	0.89
50	0.94	0.34	0.70	0.88
60	0.87	0.30	0.68	0.86
67	0.91	0.26	0.66	0.84
80	0.97	0.17	0.62	0.80
100	1.75	—	—	—

The parallel model I $Rc = \dfrac{2m(1-m)RtRo}{mRt + (1-m)Ro}$ .. (1)

The series model II $Rp = \dfrac{Rc + Re}{2}$ ..... (2)

m: the treated cotton/the untreated cotton ratio

Rt: the burning resistance of the treated cotton yarn

Rt = 1.33

Ro: the burning resistance of the untreated cotton yarn

Ro = 0.46

Rc: Rc of the equation (1), Rc = n -----

Re: the burning resistance of the untreated polyester yaran

Re = 1.06 (filling)

Re = 1.42 (the mean value of the warp and the filling)

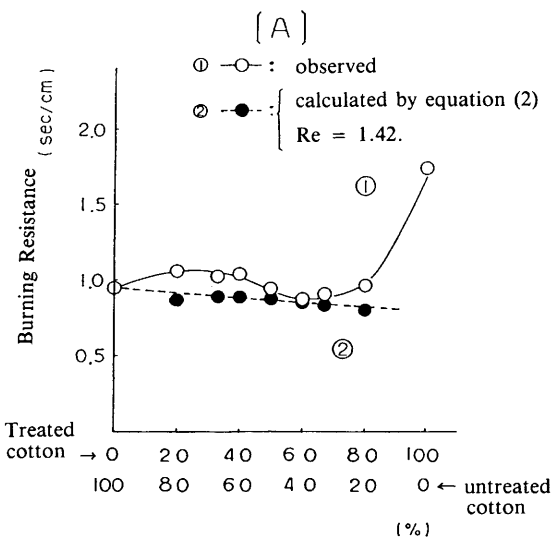


Fig 4 (A) Observed (—○—) and calculated (----●----) burning resistance for the union cloth (treated cotton yarn and untreated one: untreated polyester yarn = 50:50)

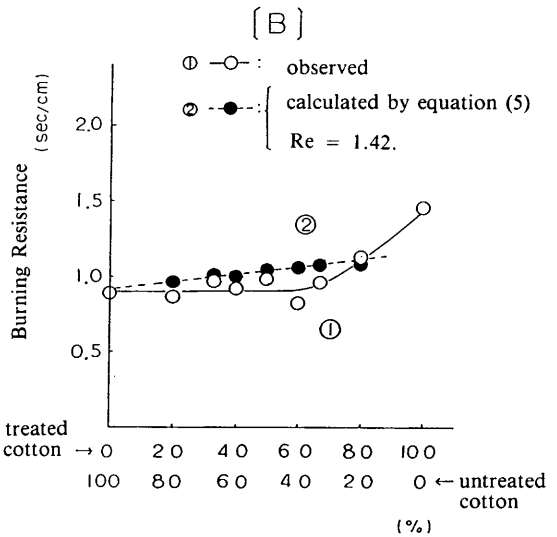


Fig. 4 (B) Obsreved (—○—) and calculated (----●----) burning resistance for the union cloth (Treated cotton yarn and untreated one: untreated polyester yarn = 50:50)

Table 3 (B) Observed and calculated values of the burning resistances for the union cloth

The ratio of treated cotton yarns (%)	The observed value (sec/cm)	Calculated by the equation (3) (sec/cm) (Rc)	Calculated by the equation (4) (sec/cm) (Rp) Re = 1.77	Calculated by the equation (5) (sec/cm) (Rp) Re = 1.77	Calculated by the equation (5) (sec/cm) (Rp) Re = 1.42
0	0.89	—	—	—	—
20	0.86	0.53	0.41	1.15	0.97
33	0.96	0.58	0.43	1.18	1.00
40	0.92	0.61	0.47	1.19	1.01
50	0.98	0.65	0.48	1.21	1.04
60	0.82	0.69	0.50	1.23	1.06
67	0.96	0.72	0.51	1.25	1.07
80	1.13	0.77	0.54	1.27	1.10
100	1.45	—	—	—	—

The series model I $Rc = mRt + (1-m)Ro$ ..... (3)

m: the treated cotton/the untreated cotton ratio

Rt: the burning resistance of the treated cotton yarn

$Rt = 0.85$

Ro: the burning resistance of the untreated cotton yarn

$Ro = 0.45$

the parallel model II $Rp = \frac{RcRe}{Rc + Re}$ ..... (4)

the series model II $Rp = \frac{Rc + Re}{2}$ ..... (5)

Rc: Rc of the equation (3), Rc = n -----

Re: the burning resistance of the untreated polyester yaran

$Re = 1.77$ (filling)

$Re = 1.42$ (the mean value of the warp and the filling)

ester yarns, Re = 1.06 (sec/cm) as that of the filling direction and Re = 1.77 (sec/cm) as that of the warp direction, is 1.42 (sec/cm). This is shown in Figure 4 (A).In the 50%-70% content range flame retardant cotton, the burning resistance calculated by equation (2) using Re = 1.42 and that observed in the A direction agrees well. Therefore, it is suggested that the agreement between a calculated using some suitable model and observed datas is almost good at the certain range in the burning resistance of the A direction.

Table 3 (B) shows the burning resistance calculated by equations (3), (4), (5) in the case of the burning resistance of the B direction. The burning resistance calculated by equation (5) using Re = 1.42 (sec/cm) in the B direction tend to approximate the observed burning resistance shown in Figure 4 (B). The reasons are not evident in this research.

EFFECT OF THE RATIO OF FLAME RETARDED FINISHED COTTON ON LIMITING OXYGEN INDEX. Figure 5 shows the effect of the ratio of the flame retarded finished cotton and the unfinished cotton on the values of the limiting oxygen index (LOI) of samples in both directions (A and B), respectively. There occurs no large difference in either direction (A or B) on the values of LOI. It shows that a maximum LOI at 30% flame retarded finished cotton content did not occur and the value of the LOI simply increased in all cases when the flame retarded finished cotton content increased.

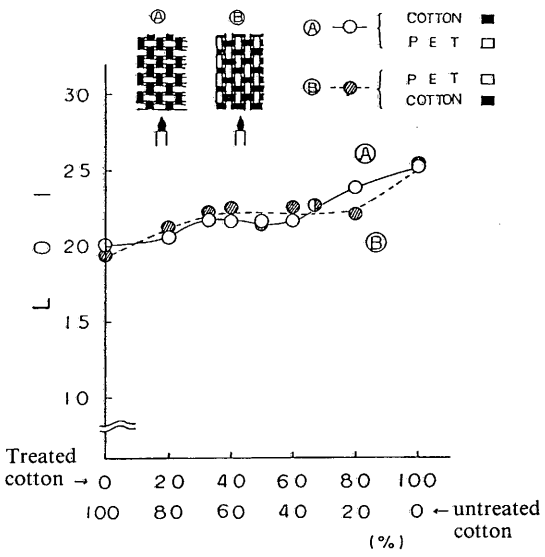


Fig. 5 Effect of the ratio of the THPC treated cotton yarn and the untreated one on the limiting oxygen index for the union cloth (cotton: PET = 0.5:0.5) A direction (—○—), B direction (---●---)

Summary and Conclusions

The purpose of this study was to investigate the flame-retardant effects of the yarn treated with the flame retardant (cotton treated with THPC as warp, polyester untreated as filling) on the flammability properties of these union cloth. The union cloth which was woven with the hand loom, was burnt in both directions (lengthwise and crosswise). The experiment was carried out by the direct ignition method using the 45 degree flammability tester and the limited oxygen index (LOI). The following conclusions were obtained.

(1) The degree of the burning resistance of union cloth when exposed under an ignition source, increased as the amount of flame-retardant finished cotton in both directions was increased. However, in the case of the union cloth showed the maximum at this point (treated cotton 30%, untreated cotton 70%) in the crossweave (A direction).

(2) The burning resistance of the union cloth was represented by the series model II (equation (2) for the A direction and equation (5) for the B direction) of the burning resistance of each single yarn using Re = 1.42 (sec/cm) which is the mean value of the burning resistance of the polyester yarns as the warp and the filling.

(3) The limited oxygen index (LOI) of the union cloth simply tend to increase with increasing the flame-retardant treated cotton yarns in both directions and there was almost no difference in their directions.

ACKNOWLEDGEMENTS The author wish to thank Japan Chemical Industry Ltd. Co. for providing the THPC, and wish to acknowledge the guidance of past prof. Dr. Nagano for this research.

Reference

1) P. Rohringer; Text. Res. J., *45*, (1975).
2) B. Miller, J. R. Molton; Text. Res. J., *46*, (1976.
3) E.M. Pintauro, D.R. Buchanam; Text. Res. J., *48*, (1979).
4) I. Holme, S.R. Patel; JSDC, *96*, 5 (1980).
5) R. Ishikubo, M. Nagano; J. Japan Res. Assoc. for Textile End-uses; *18*, 41 (1977).
6) R. Ishikubo, M. nagano; J. Japan Res. Assoc. for Textile End-uses; *20*, 36 (1979).
7) R. Ishikubo; Bull. Tokyo Kasei University *20*, 81 (1980).
8) R. Ishikubo et al.; Bull. Tokyo Kasei Univ., *23* (1983).
9) R. Ishikubo et al., Bull. Tokyo Kasei Univ., *26* (1986).

綿・ポリエステル交織織物の燃焼性

石久保　鈴　子

（平成２年９月29日受理）

綿糸とポリエステル糸をもって交織織物をつくり，綿糸の一部を防炎加工した織物のたて・よこ方向の燃焼性について，45° 法（燃焼試験）および酸素指数法で実験し，次の結果が得られた．

1）燃焼抵抗はたて・よこ方向共に，綿加工糸の増加に従って全体的に増加した．A方向の燃焼抵抗は加工綿30％付近に最大値を示した．

2）A・B方向の燃焼抵抗は，未加工綿糸，加工綿糸の並列および直列 model に，ポリエステル未加工糸のたて・よこ方向の抵抗の平均値を直列に付加した直列並列 model で示すことができた．（A方向＝(2)式，B方向＝(5)式）

3）A・B両方向のＬＯＩの値は殆んど差異はなく，加工綿糸の増加と共に単調にＬＯＩの値は大きくなった．