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Comparison of Oxygen Index Values of Different Types of Seams

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여러가지 솔기의 Oxygen Index Value에 관한 비교연구

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要　約

본 硏究의 目的은 여러 종류 솔기의 내연성을 Oxygen Index Test를 통해서 알아 봄으로서 내연가공을 한 옷에 가장 이상적인 솔기의 종류를 제시하는 데 있다.

이 목적을 위해서 6가지 종류의 솔기를 내연가공한 옷감으로 만들어 실험하였으며 솔기 종류 이외의 變因으로는 솔기제작에 사용된 실(내연가공한 실과 일반 면사)과 세탁회수가 포함되었다. 솔기의 종류는 ① 뉜솔(FF) ② 가름솔에 zig-zag로 시접처리(PZ) ③ overlock stitch로 박은 솔기(OL) ④ serger로 박은 솔기(SG), ⑤ 내연가공한 binding을 사용한 쌈솔(TB) ⑥ 내연가공하지 않은 binding을 사용한 쌈솔(UB) 등이었다.

실험 결과에 의하면 솔기 종류에 따라 O.I. value에 상당히 유의한($p<0.001$) 차이가 있었으며, 실의 종류에 따라서도 상당히 유의한($p<0.001$) 차이가, 세탁 회수에 따라서도 유의한($p<0.05$) 차이가 나타났다. 또한 솔기 종류와 세탁, 솔기 종류와 실의 종류 사이에도 상당히 유의한($p<0.001$) 상호作用이 있는 것으로 밝혀 졌다.

Newman-Keuls 검증에 의하면 TB, FF, OL 사이에는 유의한 차이가 없으며 이들은 PZ, SG(내연가공하지 않은 실), UB보다 훨신 높은($p<0.01$) 내연성을 보였다. SG의 경우 내연가공하지 않은 실을 사용했을 때는 PZ보다도 낮은 O.I. Value를 보였으나 내연가공한 실을 사용했을 때는 FF나 TB만큼 높은 O.I.결과가 나타났다. 또한 TB는 위의 솔기 중에서 가장 높은 O.I.를, UB는 가장 낮은 O.I.를 보임으로서 binding의 중요성을 나타냈다.

위의 결과로서 SG, FF, TB가 내연가공에 바람직한 솔기로 나타났으나 TB는 구성과정이 복잡하여 대량 생산에는 많이 사용되지 않으며 SG는 실의 내연가공 여부에 대한 규제가 필요한 것으로 나타났다. 또한 PZ나 UB, SG(일반 실 사용)는 내연가공한 옷생산에 사용되지 않는 것이 타당하겠다.

I. Introduction

Flame retardancy of the fabric alone cannot be used to predict the garment's burning behavior. There are many other factors that might affect the flame retardancy of finished garments.[1,2] They are most of all, garment style, seam, thread, trim, and hem. These factors can result in the failure of a prototype garment to meet the flammability standard even if the fabric from which the garment is made satisfies the criteria of the flammability standard. As Krasny[3] pointed out, however, there is a lack of systematic, quantitative knowledge about the effect of garment parameters(design, fit, combinations of outwear and underwear) on burn injuries.

Investigations into the effect of seam construction upon flammability have been few.[1] Considering the number of variables involved, and the number of possible assemblies, the scarcity of the work in this area is not surprising. There are many factors that can contribute to seam flammability, either independently or in combination, producing a complex total that makes prediction of seam flammability difficult. The factors contributing to seam flammability identified by Jakes[4] include fabric(fiber chemical type; fiber and yarn size, geometry, construction; fabric geometry; fabric finish), thread(chemical type; geometry; lubricant), seam geometry(Federal seam class; Federal stitch type; stitch density; seam allowance), seam production(thread tension, sewing speed; thread lubricant), and renovation procedures(geometric changes due to shrinkage, growth; changes in flammability or flame retardant resistance due to laundering conditions, residue buildup, lubricant removal, seam abrasion). Bixler[5] and Jakes[4,6,7] reported evidences showing effects of some of the variables on seam flammability.

Even if the Flammability Standard established by the Consumer Product Safety Act in the United States(DOC FF 3-71)[8] does not require laundering of garments provided that the fabric from which the garment is produced has shown to meet the laundering requirement, renovation procedures may produce changes in seam geometry, stitch density, thread tension, and seam mass, and may otherwise produce alterations.[4] This study was designed to reveal the effect of the selected variables to seam flammability.

I-1. Statement of the Problem

The problem of the study was to compare the Oxygen Index values of six different types of seams to determine the effect of seam geometry on seam flammability and, also, to identify the effects of thread and washing on the seam flammability. The specimens were prepared from 70/30 cotton/wool blend fabric treated with flame retardant finish, using flame retardant treated and non-treated threads. The specimens were tested before and after washings to determine the effect of washing on the seam flammability.

I-2. Hypotheses

The hypotheses of the study were:

1. There is no significant difference between or among the Oxygen Index values of:
   a. different types of seams
   b. different types of threads
   c. different number of washings
2. There is no significant interaction between:
   a. types of seams and number of washings
   b. types of threads and number of washings

II. Procedures

II-1. Flame Retardant Treatment

Used in this investigation was a plain woven fabric prepared from intimate fiber blend of 70 percent cotton and 30 percent Wellset wool(Chlorine/Hercosett 57 Shrinkproof Wool from Wellman Industries) weighing 33.3oz/sq. yd., its construction being 50 ends/in. of 24s and 52 picks/in of 24s. The flame retardant chemical used was tetrakis(hydroxymethyl) phosphonium chloride (THPC, 80% solution, Hooker Chemical Co.) The other chemicals used were trimethylol melamine(TMM, Monsanto Co., Resloom HP), and a nonionic wetting agent(Rhom and Hass Co., Triton X-100). The sodium hydroxide was a reagent grade and urea was a technical grade.

The aqueous THPOH treating solution was prepared by slowly adding aqueous 50 percent NaOH solution to THPC, stirring at room temperature until a pH in the range of 7.3 to 7.5 was obtained. The mole ratio of THPC: TMM: urea finish was 2 : 1 : 4. The solution also contained 0.1% Triton X-100 on the weight of THPC 80% solution. The fabric was padded at room temperature with the solution at 80±2% wet pickup, dried at 85°C for $2\frac{1}{2}$ minutes and cured at 160°C for $2\frac{1}{2}$ minutes.

II-2. Preparation of the Specimen

Six different types of seams were prepared with two different types of threads. Following are the symbols of the seams and the thread types used in the study:

1. Types of Seams:
   - FF: flat-fell seam
   - PZ: plain seam with zigzag edge finish
   - OL: overlock stitched seam
   - SG: serged seam
   - UB: bound seam with non-treated binding with flame retardant
   - TB: bound seam with flame retardant treated binding
   - WS: specimen without seam

The geometries of the seams are also illustrated in Figure 1.

2. Types of Threads:
   - FR: flame retardant finished thread "Cool-It" from American Thread Company, which was a stabilized spun polyester two cord thread.
   - NT: regular cotton thread "Winton", mercerized three cord.

The Viking sewing machine was used for the preparation of all specimens except the serged seam. The machine was set on 2.5 for stitch length (12 stitches per inch) throughout the specimen preparation with the exception of the zig-zag and overlock stitches. For zig-zag stitch, the machine was set on 3 for stitch width and on 1.5 for stitch length. For the overlock stitch, the machine was set as indicated in the manual. A serger was used for the serged seam.

II-3. Washing Procedure

The specimens prepared with NT thread were tested for the Oxygen Index (O.I) values before washing, after 1 washing, and after 5 washings, and the specimens with FR thread were tested only initially without washing.

The specimens were washed using "Tide" as a detergent as per AATCC 124 wash condition II(120±5°F). Dummy sheets were added to make a total load of 4 pounds, and the washer was set for a 12-minute washing cycle on the normal settings. The load was tumble dried (AATCC Method B) for 30 minutes. A Kenmore Automatic Washer and Drier were used for the washing and drying.

II-4. Oxygen Index Test Procedure

The O.I. values were obtained using the Oxygen Index/Smoke Densitometer (Michigan Chemical Corporation, Chicago, Illinois), and the specimens were tested according to the procedure described in the manual. The O.I. values were calculated as:

$$\text{Oxygen Index} = O_2/(O_2+N_2)$$

where N_2 is the volumetric flow of the nitrogen, cc/sec., at the concentration determined, and O_2 is the corresponding volumetric flow of the oxygen, cc/sec. The test was repeated three times for each set of the specimens with different flow rate of the nitrogen.

II-5. Analysis of Data

Data from the O.I. test were analyzed for:

1. Analysis of variance by a factorial design to determine the differences between each of the specimen groups and the interaction of the variables.
2. The Newman-Keuls Test to determine which pairs of the specimen groups have significant differences.
3. Means of different levels of each factor to determine the direction of significant differences and interactions.

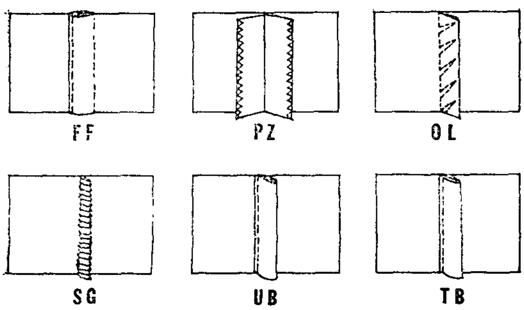

Fig. 1. Types of seams and their symbols

III. Results and discussion

III-1. The Oxygen Index Test Results

The results of the oxygen index test are given in Table 1 and 2. The figures are the averages of three values with varying nitrogen flow rates. The O.I. value of the control fabric (non-treated with flame retardant finish) without seam was 0.2015 with the

Table 1. Oxygen Index Values of NT Specimens Before and After Washings

Specimen Identification	Number of Washings			Difference Between 0-5 Washings
	0	1	5	
FF-NT	0.2955	0.2864	0.2764	0.0191
PZ-NT	0.2746	0.2635	0.2540	0.0206
OL-NT	0.2916	0.2846	0.2770	0.0146
SG-NT	0.2687	0.2696	0.2649	0.0038
UB-NT	0.2467	0.2526	0.2452	0.0015
TB-NT	0.2965	0.2897	0.2777	0.0188
WS	0.3004	0.2842	0.2775	0.0229
Control Fabric[a]	0.2015			

[a]without seam

Table 2. Oxygen Index Values Before Washing with Different Types of Threads

Seam Type	Thread Used		Difference
	NT	FR	
FF	0.2955	0.2938	−0.0017
PZ	0.2746	0.2871	0.0125
OL	0.2916	0.2892	0.0076
SG	0.2687	0.2937	0.0250
UB	0.2467	0.2466	−0.0001
TB	0.2965	0.2945	−0.0020

standard deviation of 0.0023.

The results in Table 1 show that the O.I. values of the seams decreased as the number of washings increased. Among the speciments, WS (Specimens without seam) decreased most, followed by PZ and FF.

The effect of the flame retardant treatment used in this study can also be identified in the Table 1 by comparing the initial O.I. values of WS (0.3004) and the control fabric without seam (0.2015).

The effect of the thread type on the seam flammability is illustrated in Table 2. Flame retardancy of the thread affected SG most increasing its O.I. value by 0.0250, while the O.I. values of FF, UB, and TB decreased slightly.

III-2. Analysis of Variance

As shown in Table 3 and 4, there were very highly significant ($p<0.001$) differences among the O.I. values of different types of seams, and between different types of threads. There was a significant difference ($p<0.05$) among different number of washings. Among the variables, there were very highly significant ($p<0.001$) interactions between the seam type and the number of washings, and between the type of seam and type of thread.

Table 3. Analysis of Variance: Seam Type and Washing[a]

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F-ratio
Type of seam	6	0.0046	0.0008	71.4433***
Number of Washings	2	0.0001	0.0001	5.0861*
Type of seam × Number of washings	12	0.0112	0.0009	87.2502***
Error	42	0.0004	0.0000	

*$p<0.05$
***$p<0.001$
[a]The specimens with NT thread

Table 4. Analysis of Variance: Seam and Thread Types[a]

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio
Type of seam	5	0.0025	0.0005	41.5085***
Type of thread	1	0.0007	0.0007	56.2133***
Type of seam × Type of thread	5	0.0080	0.0016	135.3960***
Error	24	0.0003	0.0000	

***$p<0.001$
[a]The specimens before washing

Table 5. Newman-Keuls Test: Different Types of Seams with NT Thread

	TB 0.2880	WS 0.2874	FF 0.2861	OL 0.2844	SG 0.2674	PZ 0.2640	UB 0.2482
UB 0.2482	p=7 0.0398 **	p=6 0.0392 **	p=5 0.0379 **	p=4 0.0362 **	p=3 0.0192 **	p=2 0.0158 **	
PZ 0.2640	p=6 0.0240 **	p=5 0.0234 **	p=4 0.0221 **	p=3 0.0204 **	p=2 0.0034 **		
SG 0.2674	p=5 0.0206 **	p=4 0.0200 **	p=3 0.0187 **	p=2 0.0170 **			
OL 0.2844	p=4 0.0036 **	p=3 0.0030 *	p=2 0.0016				
FF 0.2861	p=3 0.0019	p=2					
WS 0.2874	p=2						
TB 0.2880							

p	2	3	4	5	6	7
rp(5%)	3.03	3.70	4.11	4.41	4.64	4.83
Rp(5%)	0.0020	0.0025	0.0028	0.0030	0.0031	0.0032
rp(1%)	4.21	4.89	5.32	5.63	5.88	6.08
Rp(1%)	0.0028	0.0033	0.0035	0.0038	0.0039	0.0041

*$p<0.05$ **$p<0.01$

Table 6. Newman-Keuls Test: Different Types of Seams with FR Thread

	WS 0.3004	TB 0.2945	FF 0.2938	SG 0.2937	OL 0.2892	PZ 0.2871	UB 0.2466
UB 0.2466	p=7 0.0538 **	p=6 0.0479 **	p=5 0.0472 **	p=4 0.0471 **	p=3 0.0426 **	p=2 0.0405 **	
PZ 0.2871	p=6 0.0133 **	p=5 0.0074 **	p=4 0.0067 **	p=3 0.0066 **	p=2 0.0021		
OL 0.2892	p=5 0.0112 **	p=4 0.0053 **	p=3 0.0046 **	p=2 0.0045 **			
SG 0.2937	p=4 0.0067 **	p=3 0.0008	p=2				
FF 0.2938	p=3 0.0066 **	p=2					
TB 0.2945	p=2 0.0059 **						
WS 0.3004							

p	2	3	4	5	6	7
rp(5%)	3.03	3.70	4.11	4.41	4.46	4.83
Rp(5%)	0.0022	0.0028	0.0031	0.0033	0.0035	0.0036
rp(1%)	4.21	4.89	5.32	5.63	5.88	6.08
Rp(1%)	0.0032	0.0037	0.0040	0.0042	0.0044	0.0046

**$p<0.01$

III-3. The Newman-Keuls Tests

According to the results of the Newman-Keuls test, there were highly significant ($p<0.01$) differences among the O.I. values of all different types of seams with NT thread, except the O.I. values between FF and TB, WS and TB, WS and FF, and FF and OL. In another words, there wasn't significant difference among the O.I. values of FF, TB, OL, and WS when made with NT thread (see Table 5).

Among the O.I. values of the seams with FR thread, there was no significant difference among FF, TB, and SG (see Table 6). All the other pairs of seam types were found to be significantly different in their O.I. values.

III-4. Findings Related to the Hypotheses

The results of the statistical analyses indicated significant differences among some of the different types of seams, different types of threads, and different number of washings. A significant difference was also found between some of the seams and the specimens without seam. Thus, the hypothesis one was partially rejected.

Both parts of the hypothesis two were rejected, because it was found that there were very highly significant interactions between types of seams, and number of washings, and between types of threads and number of washings.

V. Summary and Conclusions

The study attempted to compare the Oxygen Index Values of six different types of seams. The other variables of the study besides the seam type were thread type and number of washings. The threads used in the study were regular cotton thread and flame retardant treated polyester thread. The seams included in the study were flat-fell seam (FF), plain seam with zig-zag edge finish (PZ), overlock stitched seam (OL), serged seam (SG), bound seam with non-treated binding with fiame retardant treatment(UB), and bound seam with flame retardant treated binding (TB). The speciments without seam were also tested for the purpose of comparison.

According to the results of the Oxygen Index test, bound seam with flame retardant binding, flat-fell seam, and overlock seam had relatively higher O.I. values without any significant difference among them, compared to the plain seam with zig-zag edge finish, serged seam with non-treated thread, and bound seam with non-treated binding.

Bound seam with flame retardant binding had the highest O.I. value, while the same seam with non-treated binding showed the lowest. This result challenges the Federal flammability standard which does not require the prototype test for the bindings.

There was a big difference between the O.I. values of the serged seams with non-treated thread and with flame retardant treated thread. The serged seam with flame retardant thread had the O.I. value as high as the bound seam with flame retardant binding and as the flat-fell seam, while the serged seam with non-treated thread before washing had even lower O.I. value than the plain seam with zig-zag edge finish which was usually considered as the least desirable seam type for flame retardancy. Since the serged seam is very popular for the commercial garment production, the regulations on the thread type used for the children's sleepwear manufacturing would be desirable.

The bound seam with flame retardant binding had the highest O.I. value among the six different types of the seams included in the study. The bound seam, however, is not popular either in home sewing or in commercial garment production because of the complex construction procedure.

The flat-fell seam and the serged seam with flame retardant thread are recommended. The plain open seam, serged seam with non-treated thread, and the bound seam with non-treated binding are recommended to be eliminated from the production of children's sleepwear.

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