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Development of flame retradant finish for cotton casement fabric

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ABSTRACT : The present study was conducted to develop a flame retardant finish for cotton casement fabric and to develop textile products for household use using the finished fabric. The flame retardant finish was developed by using the chemical tetrakis (hydroxymethyl) phophonium chloride (THPC) along with citric acid as binder and sodium hypophosphite as catalyst. The optimisation of pH, concentration of binder, concentration of catalyst and concentration of THPC was done by testing the effect of the finish at different variables on physical properties- tensile strength, flexural rigidity, thickness, GSM and whiteness index. The flammability was tested using Vertical Flammability tester. The results showed that pH 7, binder concentration of 10 and 0.75 per cent of catalyst and 30 per cent concentration of THPC were considered optimum for preparation of finish. At these conditions tensile strength decreased and flexural rigidity increased but in permissible limits. It was found that the developed finish was semi durable and would last for 15-20 washing cycles. The optimised laundry procedure suggested that the flame retardant casement and poplin fabrics should be washed with non ionic detergent with 2g/l concentration at 25^{o}C temperature to maintain its durability till 15-20 home launderings. The flame retardant fabric can be utilised for making textile products for use in kitchen and home furnishings.

Key words: Durability, finish, flame retardant, flammability, optimisation

Safety of human beings has been an important issue all the time. Almost all textiles are combustible materials and have been a major cause of death during their use. In the recent years, decided advances have been made in the development of durable flame proofing treatments for textiles, with the work largely directed towards meeting the needs of the military services. The treatments developed have found civilian application primarily in the field of interior furnishings in hotels, theatres and ships but flame proof fabrics have not been offered to the public at the retail level.

Cellulose fabrics, mainly cotton fabrics, meet up the level best demand of the crucial human clothing needs. It also renders prominent usage to the home furnishing, interior fabrics, tent cloths, carpets, industrial fabrics and so on (Rearick and Wakelyn, 2000). At the same time, cotton fabrics, being organic materials, retain severe flammability characteristics which is not desirable. In today's competitive and combative environment, use of cotton fabric always faces the question of safety, as it is highly flammable. Fatalities from flammable fabric were exercised for couple of centuries, and hence continuous efforts were done to minimize the trouble.

There are several variables that add to the life of the flame retardant fabrics. Some fabrics are innately flame resistant such as Nomex and some attain flame resistance through special flame retardant treatments such as cotton and its blends. The permanence of the treatment can vary from very limited to the whole life of the garment. For chemically after-treated textiles the durability depends on the strength with which the formulation adheres to the fibre surface and/or molecules (Hongkun and Sun, 2009). Some functional finishes are as durable as the fibre structure itself. But majority has a durability level, which is limited to specific end-uses only.

The measurement of textile flammability require some sort of scientific test or the use of standard test methods. The scientific tests provide information appropriate for accessing the burning behaviour and are used for the preparing new fire retardant treatments. Whereas, standard test methods make use of simple ignition tests which correspond to another approach for the assessment of the flame retardancy of a textile material. Standard gas flame is applied to the lower edge of a vertically adjusted fabric sample, ignition is observed by normal observations and time required to ignite the specimen is recorded. The textile material does not pass the test on the removal of ignition source, the flame accomplishes the end of the sample (Salmeia *et al.*, 2016).

For saving the human life and to prevent mutilation from burns caused by flaming of textiles, it is necessary to flame retard those fabrics which catch fire easily. In India flame retardant fabrics are not available in the market. So there is a need to develop such fabrics and products which the home makers can use as kitchen wear and for other household uses.

MATERIALS AND METHODS

Casement cotton fabric was procured from the local market and scoured to remove impurities. To confirm that the fabric procured for the study were made up of pure cotton fibres, burning and chemical tests were conducted. Fabric thread count were determined by a pick glass. Tetrakis (hydroxymethyl phosphonium chloride) THPC was used as flame retardant chemical, citric acid as a binder and sodium hypophosphite as a catalyst. For developing the finish, optimization of pH media, binder concentration, catalyst concentration and concentration of flame retardant chemical for cotton casement fabric was done on the basis of their effect on the physical properties such as GSM, thickness, tensile strength, flexural rigidity, whiteness index and flame retardancy. The finish was applied to the fabric using pad-dry-cure method at the optimized values. The durability of the finish to washing fastness was studied using standard test methods.

RESULTS AND DISCUSSION

For developing flame retardant fabric, the different parameters were optimized on the basis of their effect on physical properties of the selected fabric. These are discussed as follows:

Optimization of pH media : The pH of the finish was optimized using three pH *i.e.* 6, 7, 8, at 20 per cent concentration of THPC, 10 per cent concentration of citric acid and 0.75 per cent concentration (of weight of binder) of sodium hypophosphite. The finish was applied on casement fabric samples at three pH levels. The effect of different pH media on the physical properties of the fabric is furnished in Table 1.

It is clear from the data in Table 1 that tensile strength decreased at all the pH levels but the strength loss was minimum at pH 7 for both warp and weft samples. The tensile strength of untreated control sample was 54.4N (warp) and 41.7N (weft) and at pH 7 it reduced to 51.3N (warp) and 37.7N (weft) and this is because of the fact that curing at high temperature results in loss of tensile strength of the finished samples. A similar trend in results was reported by Mamalis *et al.*, 2001. Further, the table shows that the overall flexural rigidity increased after giving the flame retardant finish at different pH levels but the increase was not very high and it was minimum at pH 7. The untreated control samples of casement had thickness 0.55mm and after the application of finish, it increased to 0.58 mm at both pH 7 and pH 8 and 0.56 mm at pH 6. The GSM of the untreated casement fabric was 202.88 g/m^2 which increased to 204.0 g/m^2 at pH 6, 205.12 g/m^2 at pH 7 and 204.4 g/m^2 at pH 8. The CIE lab values furnished in the table shows that the L value which depicts lightness and darkness of the fabric was 83.41 in case of untreated fabric and after applying the flame retardant finish at different pH levels the fabric samples became lighter *i.e.* 86.04 at pH 6, 84.92 at pH 7 and 86.37 at pH 8. On the other hand the positive "a" values of fabric treated with flame retardant finish show that they were towards red at 6 and 7 pH levels but at pH 8 it was negative which means it was more towards yellow. The negative b values of both untreated and treated samples at three different pH levels depict that they were towards blue. From the above discussion it can be concluded that at pH 7 of the flame retardant finish, the tensile strength loss was minimum and increase in overall flexural rigidity was also less. The other physical properties showed no negative effects on the fabric after the application of finish. Therefore, pH 7 was considered optimum and selected for the next step *i.e.* optimization of binder concentration.

Table 1. Effect of different pH media on physical properties of cotton casement fabric

Fabric sample	Different pH concentrations			
	Control	6	7	8
Tensile strength (warp) N	54.4	48.7	51.3	50.4
Tensile strength (weft) N	41.7	35.8	37.7	35.0
Overall flexural rigidity (mg/cm)	2.53	3.86	3.22	3.37
Fabric thickness (mm)	0.55	0.56	0.58	0.58
Fabric GSM (g/m^2)	202.88	204.0	205.12	204.4
Whiteness index L values	83.41	86.04	84.92	86.37
a values	1.71	0.55	1.20	-1.53
b values	-5.69	-6.84	-6.62	-3.99

Optimization of binder concentration : For the optimization of binder, three concentrations *i.e.* 8, 10 and 12 per cent of citric acid were used at pH 7. The concentration of THPC was also kept constant *i. e.* 20 per cent. The effect of the different binder concentrations on physical properties of the fabric samples is shown in Table 2.

Table 2. Effect of different binder concentrations on physical properties of cotton casement fabric

Fabric sample	Binder concentration (%)			
	Control	8	10	12
Tensile strength (warp) N	54.4	50.7	52.3	48.2
Tensile strength (weft) N	41.7	40.2	40.9	39.4
Overall flexural rigidity (mg/cm)	2.53	3.31	3.42	3.71
Fabric thickness (mm)	0.55	0.59	0.60	0.58
Fabric GSM (g/m^2)	202.88	205.92	205.6	208.32
Whiteness Index L values	83.41	85.98	87.36	87.93
a values	1.71	0.11	-1.94	-2.73
b values	-5.69	-5.34	-4.35	-3.85

It is clear from the data in Table 2 that the tensile strength decreased in both warp and weft direction after applying the finish at three different binder concentrations. But the strength loss was minimum at 10 per cent concentration. Flexural rigidity increased with the increase in binder concentration and it increased from 2.53 mg/cm (control) to 3.31 mg/cm at 8 per cent concentration, 3.42 mg/cm at 10 per cent concentration and 3.71 mg/cm at 12 per cent concentration of binder. Although it increased with the increase in binder concentration but

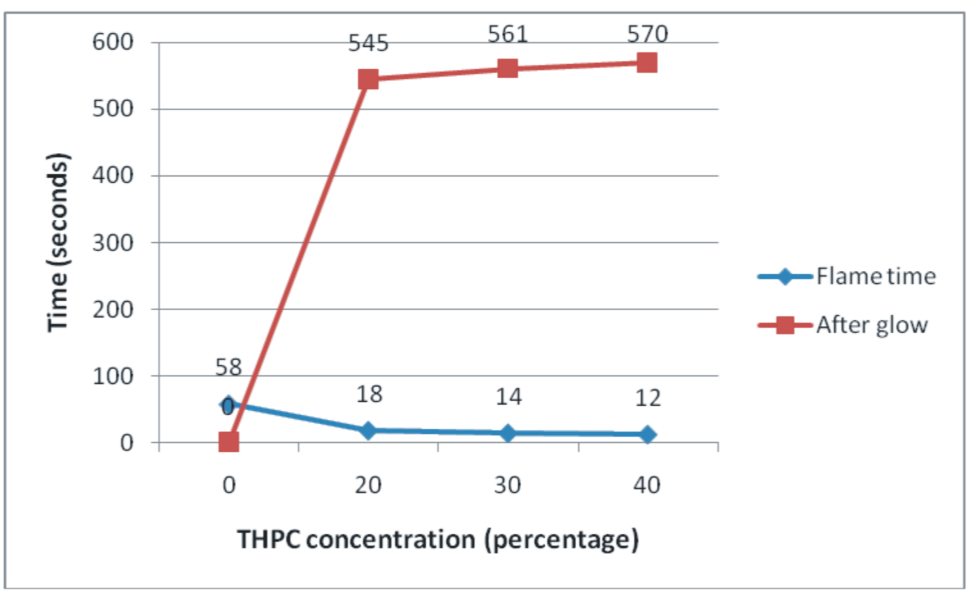

Fig 1. Effect of different THPC concentrations on flammability of casement fabric

Table 3. Effect of different catalyst concentrations on physical properties of cotton

Fabric sample	Catalyst concentration (%)			
	Control	0.75	1.0	1.25
Tensile strength (warp) N	54.4	50.6	49.1	49.7
Tensile strength (weft) N	41.7	36.2	35.8	35.4
Overall flexural rigidity (mg/cm)	2.53	3.27	3.45	3.53
Fabric thickness (mm)	0.55	0.57	0.57	0.56
Fabric GSM (g/m^2)	202.88	205.92	205.88	204.68
Whiteness index L values	83.41	84.53	85.38	85.92
a values	1.71	0.48	0.23	0.65
b values	-5.69	-5.81	-6.70	-6.89
casement fabric				

the difference was marginal. The thickness of the fabric also increased after the finished was applied at three concentrations of binder. The GSM of the untreated fabric was 202.88 g/m^2 which increased to 205.92 g/m^2 at 8 per cent concentration, 205.60 g/m^2 at 10 per cent and 208.32 g/m^2 at 12 per cent concentration. The increasing L values towards 100 shows that the fabric samples became more white after treating them with flame retardant finish at different binder concentrations. After analyzing the effect of different binder concentrations on physical properties of the fabric, 10 per cent binder concentration was considered to be optimum as tensile strength was least affected at this concentration and also the increase in the overall flexural rigidity at this concentration was less as compared to other concentrations. Hence, it was selected for the further experiments for the optimization of catalyst concentration and THPC concentration.

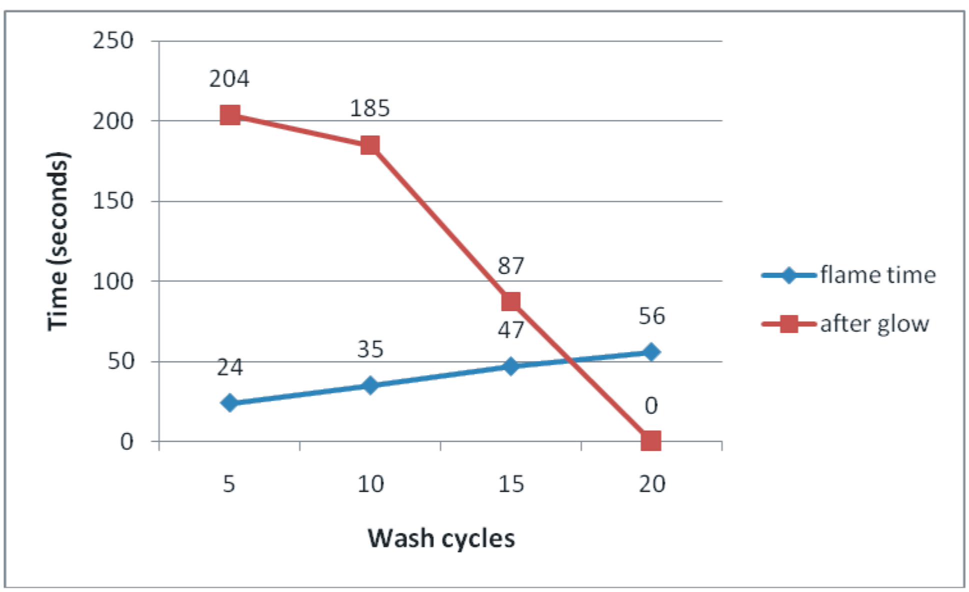

Fig 2. Effect of washing on flame retardancy of finished casement fabric

Optimization of catalyst : For the optimization of catalyst, there concentrations *i. e.* 0.75, 1.0 and 1.25 (of the weight of the binder) were selected and applied on fabric samples with 20 per cent THPC, 10 per cent binder and pH 7. The effect on the physical properties of the fabric was studied and results are given in Table 3.

Data in Table 3 depicts the effect of different catalyst concentrations on the tensile strength of casement fabric. There was decrease in the tensile strength at all three catalyst concentrations in both warp and weft directions. It was 50.6N (warp) and 36.2N (weft) at 0.75 per cent concentration which shows minimum strength loss. The flexural rigidity increases with the increase in the concentration of catalyst but the difference is marginal. The overall flexural rigidity of fabric at 0.75 per cent increased to 3.27 mg/cm, at 1.0 per cent it increased to 3.45 mg/cm and at 1.25 per cent it went up to 3.53mg/cm. The thickness also increased after application of flame retardant finish on the fabric with different concentrations of catalyst. The thickness of increased to 0.57mm at 0.75 and 1.0 per cent but at 1.25 per cent it increased only to 0.56mm. The GSM of the untreated casement fabric was 202.88g/m^2 and increased to 205.92 g/m^2 at 0.75 per cent concentration of catalyst which was maximum. It further decreased a little at 1.0 per cent concentration and at 1.25 per cent it was only 204.68 g/m^2. The table also shows that increasing L values towards 100 depict that the samples became more white when the flame retardant finish was applied at different catalyst concentrations. The positive a values at all levels of catalyst concentrations show that the treated fabric samples were towards red and the negative b values of all the samples show that they were towards blue. Hence, from the above discussion it was concluded that the catalyst concentration 0.75 per cent was optimum because the loss in tensile strength was minimum at this concentration and the increase in overall flexural rigidity was also less. Therefore, it was selected for the taking the study to the next step i.e. optimization of flame retardant chemical THPC for developing the final finish.

Optimisation of THPC concentration : For the optimization of THPC, three concentrations *i.e.* 20, 30 and 40 per cent were selected and applied on fabric samples with 10 per cent binder , 0.75 per cent catalyst (on the weight of the binder) and at pH 7. The effect on the physical properties of the

Table 4. Effect of different THPC concentrations on physical properties of cotton casement fabric

Fabric sample		THPC concentration (%)			
		Control	20	30	40
Tensile strength (warp) N		54.4	50.9	50.0	49.6
Tensile strength (weft) N		41.7	37.3	38.0	37.2
Overall flexural rigidity (mg/cm)		2.53	3.51	4.91	5.27
Fabric thickness (mm)		0.55	0.57	0.61	0.63
Fabric GSM (g/m^2)		202.88	205.76	206.56	208.92
Whiteness index	L values	83.41	84.69	84.47	84.53
a values		1.71	2.03	0.85	0.48
b values		-5.69	-7.80	-6.39	-5.81

fabric was studied and results are given in Table 4.

Results in Table 4 reveals the effect of flame retardant finished formulated with three concentration of THPC on physical properties of the fabric. The wrap wise tensile strength decreased at all three concentration levels but the difference was very less *i.e.* 50.9N at 20 per cent, 50.0N at 30 per cent and 49.6N at 40 per cent concentration. On the other hand the weft tensile strength of fabric also decreased. It was 37.3N at 20 per cent, 38.0N at 30 per cent, and 37.2N at 40 per cent concentration of THPC. The flexural rigidity increased with the increase in the concentration of THPC in the flame retardant finish applied on the fabric. It was 5.27 mg/ cm *i.e.* maximum increase at 40 per cent concentration. The thickness increased with increase in the concentration of THPC in the flame retardant finish. It increased from 0.55mm (control) to 0.57mm at 20 per cent, 0.61mm at 30 per cent, 0.63mm at 40 per cent concentration. The GSM increased with the increase in the concentration of THPC and increased maximum to 208.92 g/m^2 at 40 per cent concentration. It is also evident from the table that the L values increased depicting that the samples became lighter when treated with flame retardant finish at different THPC concentrations. Further the positive a values reveal that the samples were towards red, before and after application of the finish. The negative b values show that the fabric samples were towards blue before and after treatment with different concentrations of THPC.

Table 5. Effect of different laundry conditions on flame retardancy of finished casement fabric

Laundry conditions Type of detergent	Flammability parameters	
	Flame time(sec)	After glow(sec)
Alkaline	20.0	379.0
Non ionic	17.0	488.0
Detergent concentration		
2g/L	16.0	510.0
5g/L	20.0	402.0
Wash temperature		
25^{o}C	15.0	514.0
40^{o}C	18.0	460.0

Effect of different THPC concentrations on flammability of fabric : The effect of the different THPC concentrations on flammability of fabric was tested using Vertical Flammability test. The flame time and afterglow time was recorded and the results are furnished in Fig. 1.

It is clear from the Fig 1 that flame retardancy increased with the increase in the concentration of THPC in the finish. The untreated fabric sample when subjected to vertical flammability test showed 58 sec flame time and no afterglow time. After applying the finish with 20 per cent concentration of THPC, the flame time reduced to 18 sec and the afterglow of 545sec was observed. At 30 per cent concentration, the flame time reduced to 14 sec and afterglow increased to 561 sec. The flame time was recorded as minimum *i. e.* 12 sec at 40 per cent THPC concentration and the afterglow was recorded as 570 sec.

Thus, it can be concluded that 30 per cent concentration of THPC in flame retardant finish for casement fabric was found to be optimum because at this concentration loss in tensile strength was minimum and effect on flexural rigidity was marginal. But most importantly the flammability decreased to a large extend. Gao *et al.*, 2015 also concluded similar result. Though it showed better results at 40 per cent concentration but there was a difference of only few seconds. So 30 per cent concentration was selected to develop flame retardant finish for casement fabric

Durability of the developed flame retardant finish : To evaluate the durability of flame retardant finish on the cotton casement fabric, wash fastness of the fabric samples was tested. After washing the samples in launder-o-meter using Standard Test Method, the flammability was tested in vertical flammability tester after 5, 10, 15 and 20 wash cycles. The results are presented in Fig 2.

From Fig 2, it is evident that for cotton casement fabric samples, after 5 wash cycles, the flame time increased to 24 sec and the after glow time reduced to 204 sec. After 10 wash cycles, the flame time increased to 35 sec and after glow time decreased to 185 sec. After 15 wash cycles, the flame time increased to 47 sec and after glow time decreased to 87 sec and the flame time further increased to 56 sec with no after glow which shows that the finish was totally removed after 20 wash cycles because the untreated casement fabric showed flame time of 58 sec and no after glow. Horrocks (1996) also stated durability of flame retardant chemicals decreased after washing. Thus it can be concluded that the developed flame retardant finish has semi durability which lasts till 15-20 wash cycles.

It is evident from the data in table 7 that the cotton casement fabric samples when washed with alkaline detergent showed flame time of 20 sec and after glow of 379 sec. Whereas, in case of non ionic detergent the flame time was 17 sec and after glow time was 488 sec. So it is clear that flame retardancy is better after washing with non ionic detergent. So non ionic detergent was selected for next washing process *i. e.* detergent concentration. It is clear from the Table that at 2g/l, the flame time was 16 sec and after glow was 510 sec. But using 5g/l detergent concentration, the flame time increased to 20 sec and afterglow decreased to 402 sec which indicates decrease in flame retardancy. Therefore, 2g/l detergent concentration was considered optimum and selected for next laundry step i e optimization of wash temperature. For this laundering was done at two variable temperatures. The data in the Table further shows that at 25°C temperature the flame time recorded was 15.0 sec and after glow was 514 sec but at 40°C temperature the flame time increased to 18 sec and after glow decreased to 460 sec, which reveals that flame retardancy decreased with increase in the wash temperature. Therefore, 25° C temperature was considered optimum.

CONCLUSION

Thus flame retardant finish prepared using Tetrakis (hydroxymethyl) phophonium chloride (THPC) along with citric acid as binder and sodium hypophosphite as catalyst can be successfully applied on cotton casement fabric. The finish is semi durable and if optimal laundary procedure is followed it would last for 15-20 washings. The finished fabric can be used for making various textile products for use in kitchen and home furnishings.

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