Development of Flame retardant-finished Handloom Home Furnishing (HF) Fabric through Integrated Weaving and Finishing

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Abstract : **Home Textiles segment has an important place in the Indian Textile Export Market. Flame Retardant (FR) finished fabric has very good demand not only in the export as well as domestic market. Conventionally FR finish is applied to fabric after weaving. This paper discusses integrated weaving and finishing process developed to impart the finish over the fabric during the weaving process by attaching 'On-Loom integrated Finishing Device' on handloom.**

'On-loom integrated finishing device' is a novel technique to impart the required finish to the handloom fabric during weaving itself i.e., the finish process is integrated with the weaving process.The FR finished handloom fabrics woven using the 'On-loom integrated finishing device attached to handlooms are studied to achieve the best efficiency by optimising finish application parameters. The best efficient finished fabrics of the developed samples are compared with commercially finished fabrics of similar construction and applied with similar finish at processing mills.

IndexTerms **- Home Textiles, integrated weaving and finishing, Flame Retardant (FR),On-loom integrated finishing device, handloom**

I. INTRODUCTION

Generally, functional finishes such as 'Flame Retardant Finish', 'Water-and-Stain-repellent Finish' 'UV Protection Finish' etc. are imparted to longer lengths of fabrics at processing mills. Home Textile products like draperies / curtains, meant for export to Europe and US markets are mostly produced with FR finish. The finish is applied to the Home Textiles fabrics after weaving at Processing Units, which involves considerable additional expenses like packing and transport apart from the actual finishing cost. Therefore, an attempt has been made to apply finish over the fabric during the weaving process itself, to reduce the cost. In order to undertake the finishing process, a handloom has been attached with 'On-loom integrated Finishing Device' which consists of a Finish applicator and a Curing Chamber, used for applying the finish and cure respectively.

In this study three different sets of home furnishing samples of Coarse, Medium and Fine varieties have been taken to impart 'Flame Retardant Finish' by varying the finish parameters of concentration of finish liquor and curing temperature to find out optimum condition to get the best finish efficiency. The best sample from each fabric has been selected. The sample finished through the 'on-loom integrated finishing device' is compared with commercially available finished fabric of similar specifications.

II. MATERIALS AND METHODS

i) On-loom integrated Finishing Device

A novel device has been designed and fabricated and named as 'On-loom integrated finishing device' which consists of a Finish Applicator and Curing Chamber. The finish applicator applies the Flame Retardant finish liquor on the woven fabric on the flat faced Front Rest. The wet pickup can be adjusted through the number of strokes of the applicator. The number of strokes determines the wet pick-up percentage. Through trial and error method, the 70% wet pick up of 'Flame Retardant' finish is obtained by two strokes.

The curing chamber is between applicator and the cloth roll and cures the finish-liquor-applied fabric. The curing chamber is attached with digital controller which is used to control the temperature of the curing chamber ranging from 100°C to 250°C, and the curing time can also be controlled from 1 to 10 minutes.

For this study the time duration of 1.5 minutes has been considered as standard by synchronising the time taken for weaving, finishing and drying before the fabric reaches for curing. Based on the Literature Review, in this work, three different concentrations of finishing liquor such as 300 g/l, 350 g/l and 400 g/l have been taken, and three different curing temperatures such as 140°C, 150°C and160°C have been considered to impart 'Flame Retardant Finish'.

ii) Preparation of Flame Retardant Finish Liquor

Flame Retardant Finish Liquor consists of Tris (2-Chlorlethyl Phosphate) to impart finish and acetic acid to adjust to the pH value of 6. For example, to prepare 400 g/l concentrated 'Flame Retardant Finish' Liquor, 400 grams of Tris (2-Chlorlethyl Phosphate)chemical is dissolved in water to make it into solution of 1 litre. The acetic acid is added to adjust the pH of the liquor to the value of 6.

iii) Selection of Fabric Samples

Three different sets of handloom Home Furnishing fabrics have been considered to impart 'Flame Retardant' Finish. The selection of these handloom furnishing fabrics has been doneby assessing the demand for this kind of furnishing fabricsin the export market. The specification of the selected handloom samples has been tabulated in Table 1.

Table1 Specifications of the Home Furnishing samples chosen for the study

S.No	Fabric Sample Code	Fibre Details	Specifications			
			Count of Warp	Count of Weft	Reed	PPI
1	CH	Course Cotton Home Furnishing (HF)	2/20 s	2/20s	48	40
2	MH	Medium Cotton Home Furnishing (HF)	2/30 s	2/30S	52	44
3	FH	Fine Cotton Home Furnishing (HF)	2/40 s	2/40S	56	48

The above specified handloom fabrics were woven using the handloom attached with 'On-loom integrated finishing device'. The fabric has been applied with 'Flame Retardant finish of three different concentrations and cured at three different temperatures. The efficiency of the finish has been studied through Flame Retardancy Test (ASTM D6413/D6413M). The optimum condition to achieve the maximum efficiency has been studied for all the fabrics. The **FR Efficiency Ratings are - 6 - Excellent 5 - Very Good 4 - Good 3 -Considerable 2 - Weak .**

III. RESULTS AND DISCUSSION

Three different sets of process parameters have been considered as shown in Table 2. In a total 27 samples,3 different fabrics having 9 different finished samples have been developed. The finished samples have been evaluated for Flame Retardant efficiency.

Table 2 –Flame Retardant Efficiency- Vertical Flame Test Results for 9 different sets of process parameters

S.No	Fabric Details	FR Efficiency under 300 gpland1.5 Min			FR Efficiency under 350 gpland1.5 Min			FR Efficiency under 400gpland1.5 Min		
		140° C	150°C	160° C	140° C	150°C	160° C	140° C	150°C	160° C
1	Coarse Cotton HF	4	4	4	4	5	6	5	6	6
2	Medium Cotton HF	4	4	5	5	6	6	5	6	6
3	Fine Cotton HF	4	4	6	5	6	6	6	6	6

(Please Note) **FR Efficiency Ratings 6 - Excellent 5 - Very Good 4 - Good 3 -Considerable 2 - Weak**

Among three different concentrations, 300 gpl shows a higher efficiency rating of 6, only for Fine Cotton HF at 160°C;350gpl concentration shows a higher efficiency rating of 6 for Medium and Fine Cotton HF at 150°C and160°C respectively, while a higher efficiency rating of 6 for Coarse Cotton HF is only at 160°C.

The fine cotton Home Furnishing gets Excellent (6) FR Efficiency rating at a concentration of 300 gpl at 160°C. The medium cotton Home furnishing gets Excellent (6) FR Efficiency rating at a concentration of 350 gpl at 150°C. Coarse Cotton Home Furnishing gets Excellent (6) FR Efficiency at a concentration of 350gpl at 160°C.

Based on the above test results, the optimum process parameters to achieve higher efficiency rating are tabulated below.

Table 3 Optimum Process Parameters to achieve better Flame Retardant Efficiency ratings

S.No	Fabric Details	Process Parameters		
		Concentration of Finish Liquor	Temperature	Time
1.	Coarse Cotton Home Furnishing (HR)	350 g/l	160°C	1.5 Minutes
2	Medium Cotton Home Furnishing (HR)	350 g/l	150°C	1.5 Minutes
3	Fine Cotton Home Furnishing (HR)	300 g/l	160°C	1.5 Minutes

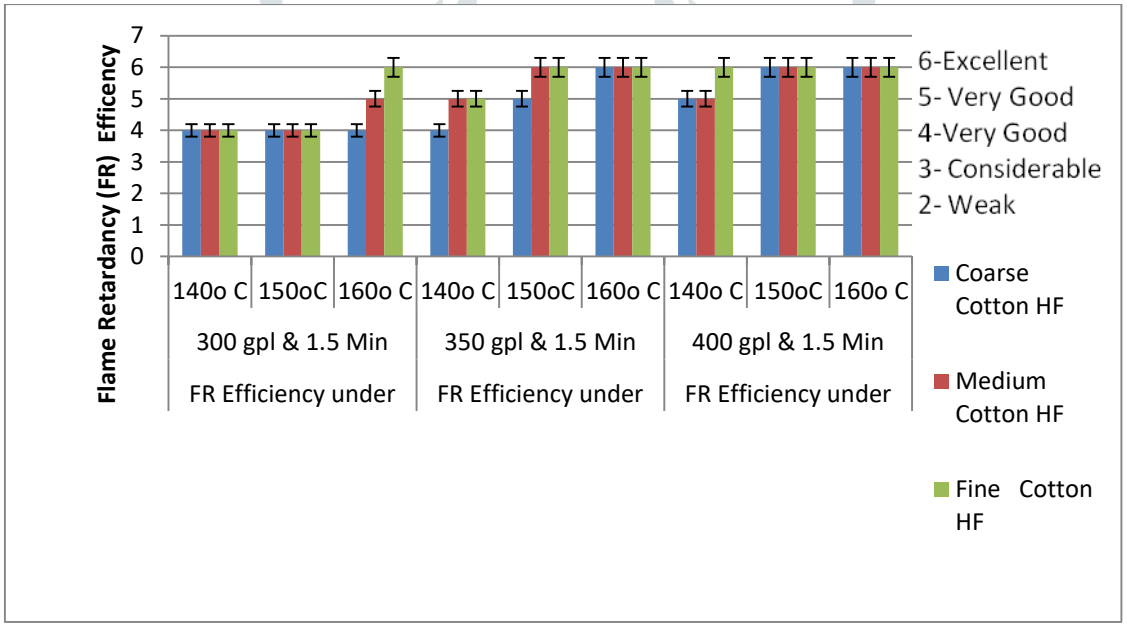


Figure 1 - Efficiency of FR finish at different conditions by ASTM D6413 /D 6413M ,Method

Each of the samples above consisting of 10 numbers of each variety applied with Flame Retardant Finish during weaving was tested for the efficiency by ASTM D6413 /D 6413M[2] ,method.The fabrics were tested for FR efficiency of finish using an auto flame chamber. A standardised flame was applied to the surface of the sample near the lower end for 12 seconds. The flammability of fabrics was measured as length of char in millimetres. The FR Efficiency Ratings are, 6 - Excellent 5 - Very Good 4 - Good 3 -Considerable 2 - Weak **.** The Efficiency of Finish under various parameters is compared to find the optimum finish parameter.

3.1 SEM & FTIR Analysis for 100% Coarse Cotton FR finished Home Furnishing samples

SEM Analysis helps to confirm the presence of FR finish on the samples. FR finish has been imparted to all the 27 samples with 3 different processing temperature and 3 different concentration. The optimised process parameters for 3 different varieties of samples have been finalised. Among 3 different materials samples such as Coarse, Medium and Fine Cotton FR finished Home Furnishing samples, Coarse Cotton Home Furnishing (HF) samples, has been analysed for the SEM & FTIR. Similar trend has been observed for the remaining two Medium and Fine Cotton Home Furnishing samples..

3.1.1 SEM Analysis

SEM images for Coarse Cotton Home Furnishing sample of unfinished fabrics and FR finished samples are shown in figures 2 (a) & 2 (b) and 3 (a) & 3 (b), with 1000 X & 2000 X magnification respectively.

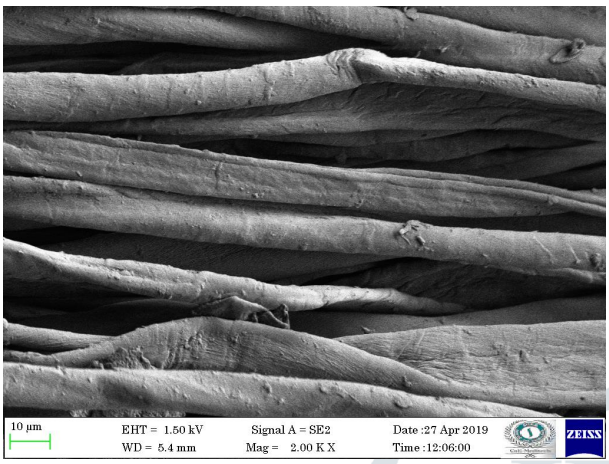


Fig. 2(a)

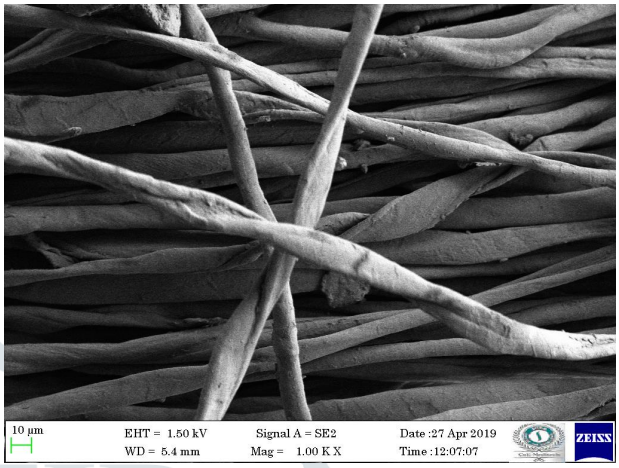


Fig. 2(b)

Figure 2 (a, b) - SEM images of unfinished Coarse Cotton Home Furnishing sample

Fig 2 (a, b) shows fibres in the untreated cotton fabric samples, the surface fibres has striations and no polymer aggregates and any other agglomerations is seen over the surface.

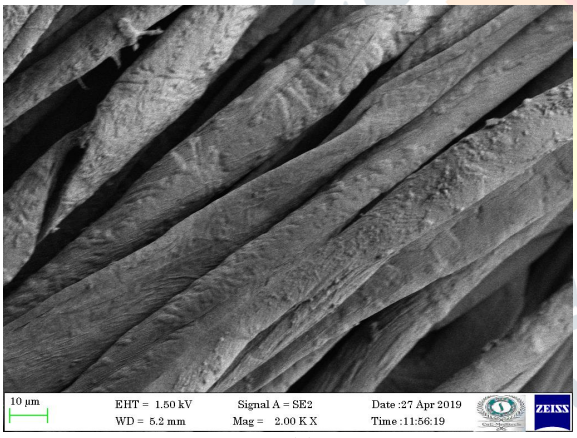


Fig. 3(a)

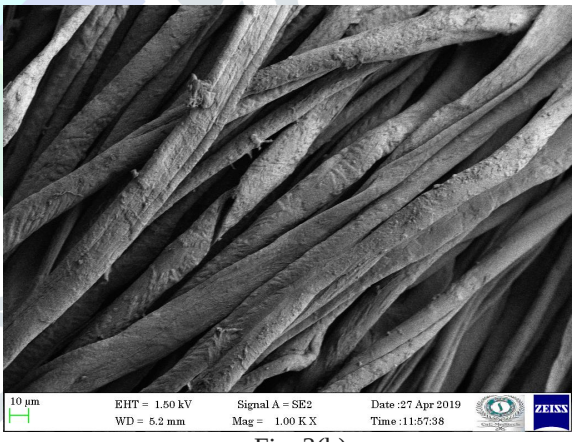


Fig. 3(b)

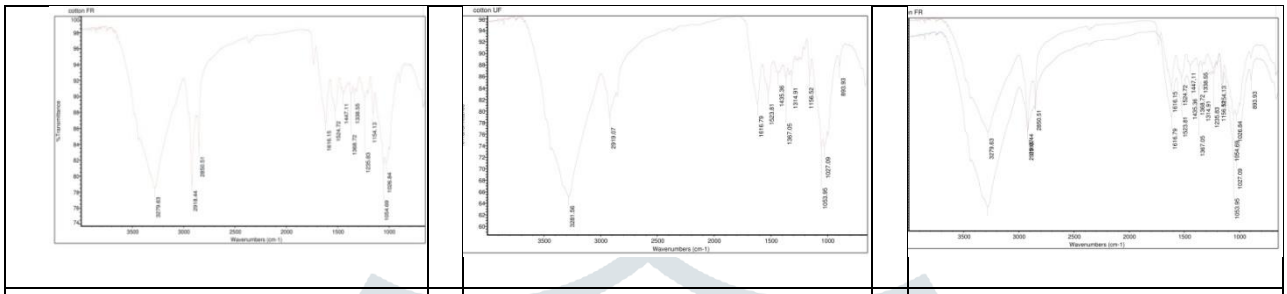
Figure 3 (a, b) - SEM images of Coarse Cotton Flame Retardant finished Home Furnishing sample

Figure 3(a) & 3(b) shows SEM images of .Coarse Cotton FR finished Home Furnishing sample, Compared to untreated sample shown in Figure 2, FR finish coating can be seen on the surface of the fibres. The coarse bumpy appearance indicates formation of polymerization on the fibre surface. Similar trend has been observed on the remaining two samples of Medium and Fine FR finished Cotton Home Furnishing fabrics.

3.2 FT- IR Analysis

IR (infrared) spectroscopy is useful to identify different functional groups, places in the IR spectrum. IR spectroscopy gives the functional groups involved in the fabric samples and also shows the interaction with the fibre molecule in the form of intensity such as Weak, Medium and Strong etc. To generate the IR spectrum, different frequencies of infrared light are passed through a sample, and the transmittance of light at each frequency is measured. The transmittance (% age) is then plotted versus the frequency of the light (Wavenumbers in the units of cm^{-1}).

Different intensities and functional groups produce band absorptions at different locations of the sample which shows in the IR spectrum. Recognizing where the absorptions generated by the common functional groups occur will help to interpret IR spectra. The Flame retardant finish treated cotton fabrics and the untreated cotton fabrics were evaluated for their absorption location and absorption intensity using Fourier Transform Infra Red spectroscopy. The test reports are shown in Figure 4(a) & (b).



4 (a)	4 (b)	4 (c)

Figure 4(a, b &c) FT-IR Spectrum of FR treated, Unfinished samples and Super imposing of both samples

Figure 4 (a) shows the FT- IR absorbance spectra of Flame Retardant treated cotton fabrics. It is observed that the band between 3200 cm^{-1} and 3600 cm^{-1} are due to O-H bond stretching frequencies and 2200 cm^{-1} and2600 cm^{-1} frequencies are due to C-H bond stretching frequencies. The presence of functional groups of Alkane (C-H), Alkyne (C-C-H) and Alkane bonds are found to be observed in the corresponding vibration modes. It means that these functional groups are more intense with the fibre molecule which is attributed to range from Medium to Strong. The common features that appear in the wavelength band range of 1000 cm^{-1} to 1110 cm^{-1} correspond to the stretching vibrations of Si=O and also to the contributions of Si-O bonds. The bands visible at 800 cm^{-1}, 1200 cm^{-1} and 1100 cm^{-1} may be assigned to the vibration of Si_6O_{18}, Si_2O_6, Si_2O_5 and SiO_2 bands for the fabric samples.

Figure 4 (b) shows the IR absorption spectra of untreated cotton fabric sample. It is observed that the band spectrum is similar to that of the treated fabric samples from 3200 cm^{-1} and 3600 cm^{-1}. However, the Alkane (C-H) and Alkyne (C-C-H) functional group bonds are relatively weak when compared to that of treated fabric samples. In addition, the presence of aromatics compounds is found to extend up to lower absorption spectra of 893 cm^{-1}.

Fig 4 (c) shows the IR absorption spectra of super imposed untreated and FR treated cotton fabric samples. It is observed that although both the fabric samples show same absorption spectra in the wave length band of 3200 cm^{-1} to 3600 cm^{-1}, the % transmittance depth is better to the level of 79% in FR treated fabric sample as compared to the untreated one which is shown by the transmittance intensity starting from 65% only. It shows that the flame retardant finish applied on the cotton fabrics is effectively absorbed by the fabrics.

IV. COMPARATIVE STUDY

The commercially available Flame Retardant Finished Fabrics in the processing mills with same construction of Coarse, Medium and Fine varieties have been considered for the comparative study.

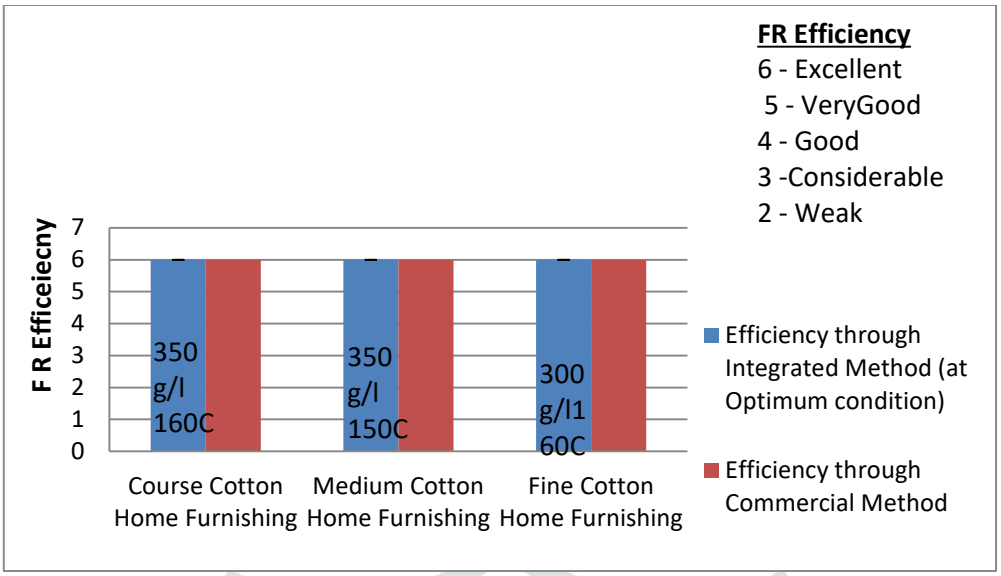


Figure 5.Comparision of Fire Retardant Efficiency of Integrated vs Conventional Finished Samples

Figure 5 shows FR Efficiency of the best three selected 'Flame Retardant' finished handloom fabrics and commercially finished fabrics of similar construction. The results show that the handloom fabric finished through On-loom integrated finishing device attachment gives the same result as commercial finished fabrics do. The study shows that the finish applied through On-loom integrated finishing device attached to the handloom is effective in comparison with commercial method of mill finishing after weaving process.

V. CONCLUSION

Design development of 'On-loom integrated finishing device' attached to a handloom is a novel finishing technique. It is used to develop value added handloom products with a special finish.

Optimum Process parameters have been obtained for three different fabrics of Coarse, Medium and Fine Cotton Home Furnishing fabrics, which are imparted with 'Flame Retardant' finish. The FR Efficiency of the developed fabric samples is compared with commercially available fabrics of similar construction. It is concluded that the developed handloom 'Flame Retardant Finished fabrics shows Excellent FR Efficiency rating of 6, as much as commercially available finished fabrics do. Thus, it is concluded that the finish applied through On-loom integrated finishing device attached to the handloom is effective in comparison with commercial method of mill finishing after weaving process.

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