AUTEX 2022 Conference Proceedings 978-83-66741-75-1 © Lodz University of Technology, 2022

DOI: 10.34658/9788366741751.5

THE EFFECT OF FLAME-RETARDANT FINISH ON JUTE AND JUTE-COTTON FABRICS

Most Setara Begum[1(*)], Abdul Kader[2], Rimvydas Milašius [1]

[1] Faculty of Mechanical Engineering and Design, Kaunas University of Technology, Studentu Str. 56, LT-51424, Kaunas, Lithuania

[2] Department of Textile Engineering, BGMEA University of Fashion and Technology, Dhaka, Bangladesh

(*) *Email:* most.setara@ktu.edu

ABSTRACT

The ligno-cellulosic Jute fiber, which holds the second largest volume among the natural cellulosic fibers after Cotton. This study is focuses on the determination of flame-retardancy properties of pure Jute and Jute-Cotton fabrics treated with Pyrovatex CP New at various concentrations (50%, 60%, 70%, 80%, 90% owf, M:L: 1:10, 1:7, 1:5). A significant improvement in the flame-retardancy was determined on both fabrics. After ignition period, the recorded flame spread time was zero second on both FR treated fabrics; on the other hand, it was measured 21 seconds and 28 seconds to burn the entire length (15 cm) of untreated Jute and Jute-Cotton fabrics, respectively. Within these flame-spread times, the char length was 2.2 cm and 2.73 cm in Jute and Jute-Cotton fabrics, respectively. Tensile and tear strength also markedly decreased markedly after the FR finish in both warp and weft directions of both fabrics. The vertical flammability results reported in this study show the potential application of Pyrovatex CP New on Jute-based materials.

KEYWORDS

Jute, Jute-Cotton, Flame-Retardancy, Flammability, Char Length, Pyrovatex CP New.

INTRODUCTION

Jute is a ligno-cellulosic fiber that contains the primary elements hemicellulose (22–24%), cellulose (58–60%) and lignin (12–14%), as well as several minor constituents. Because of the variances in the chemical composition, the thermal behavior of various components changes. The thermal behavior and fire-retardant finish have been the subject of some exploratory research in previous studies [1,2]. To limit the number of casualties and injuries caused by fire, the backing of jute carpet, decorative jute furnishing fabrics and the brattice cloth for mines have been made fire-resistant. Fire-retardant fabrics are now used in a variety of applications, including floor coverings, floor mats, carpets, military uniforms, hospital furniture, hospital curtains, and industrial ventilation, among others [3]. Higher chemical add-on, visible decrease in tensile strength, and yellowing are the main issues with the fire-protective finish treatment of jute-based fabrics. Furthermore, the majority of these fire-retardant compositions are not durable or semi-durable and require substantial dosages of relevant chemicals [4]. Except cotton, limited studies were conducted on natural fibers, but the studies by Yusuf [5] on linen, hemp, silk & wool and on flame-retardancy of jute by Mehta & Hoque [6]. Dorez et al. investigated the effects of the content of cellulose, hemicellulose, and lignin on the pyrolysis and combustion of natural fibers [7]. Previous studies reported the application of different organophosphates and other chemicals in Jute [8] and in a recent study, Samanta et al. have successfully investigated the effect of nano-zinc oxide as a flame-retardant finish on Jute fabric [9].

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Previous researchers conducted several studies on the application of Jute fibers in composites [10,11], but very few were determined the flame-retardancy of Jute fabrics for the purpose of technical textiles. Therefore, this paper focuses on determining the flame-retardance property of 100% Jute and Jute-Cotton fabrics treated with a commercial flame-retardant (FR) chemical and thus on investigating the impact of flame-retardant finishing on the physio-mechanical properties of the fabrics.

EXPERIMENTAL

Materials, chemicals and flame-retardant finishing treatment

All experiments were carried out using two different plain woven fabrics (pretreated) consisting of 100% Jute (290 GSM, EPI: 22, PPI: 16) and Jute-Cotton (Warp: Cotton and Weft: Jute; 340 GSM, EPI: 52, PPI: 26), purchased from Mony Jute Company, Dhaka, Bangladesh. A phosphorous-based commercial flame-retardant chemical, PYROVATEX CP New (N-methylol dimethylphosphonpropionamide) and cross-linking agent KNITTEX FFRC (a modified dihydroxy ethylene urea) were purchased from the local agent of Huntsman (Swiss Color, Bangladesh). All chemicals were used as received.

100% Jute fabric was treated with PYROVATEX CP NEW by the exhaust method at varying concentrations (50%, 60%, 70%, 80%, 90% owf or 128.57 g/L, 114.28 g/L, 100 g/L, 85.71 g/L, 71.43 g/L)) with the material-to-liquor ratio 1;10, 1:7 and 1:5 in an open bath at room temperature for 1 hour. The KNITTEX FFRC crosslinking agent was used at 30 g/L for all treatment baths. Similarly, the Jute-Cotton fabrics were treated in a material-to-liquor ratio 1:7, the other treatment conditions remained the same as the Jute fabric treatment. Finally, the treated samples were then dried in air.

Flammability test

The untreated and flame-retardant (FR) treated fabrics were tested using a vertical flammability test followed by the standard method DIN 4102-1. The specimen size was kept 15 cm in length and 5 cm in width and exposed to a standard flame at 90º vertically using a Bunsen burner for 10 seconds of ignition time; the flame source is then removed and left for further burning. Afterwards, the flame spreading time, after glow time and char length was recorded. All tests were repeated three (03) times.

Physio-mechanical properties analysis

For the tensile strength test and the elongation at the break, the maximum force was determined using the grab method (EN ISO 13934-2). The tear force was determined using the single tear method (EN ISO 13937-2(auto-stop)). All these tests were repeated three (03) times.

RESULTS AND DISCUSSIONS

Determination of flammability

After application of the flame-retardant chemical to the Jute and Jute-Cotton fabric, the vertical flammability test was determined. The ignition time was kept constant at 10 sec, then the flame source was removed, and the flame spread time, after-glow time, and char length were determined, presented in Table 1. Initially, the Jute fabric was treated with the flame-retardant chemical at five different concentrations (50%, 60%, 70%, 80%, 90% owf) in three different material-to-liquor ratios (1:10, 1:7, and 1:5). Apparently, after gaining the best flame-retardancy performance in the treated Jute fabrics at 1:7 material-to-liquor ratio, the Jute-Cotton fabric was treated with the same concentrations of Pyrovatex CP New in 1:7 material ratio and measured the performance.

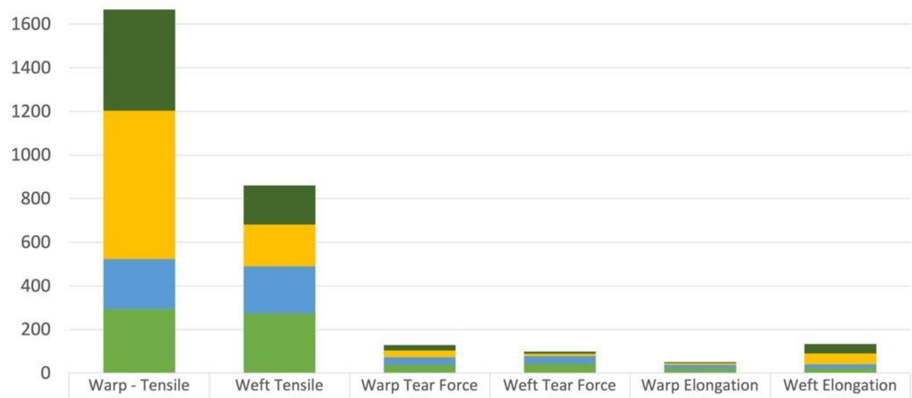
Table 1. Vertical Flammability results of Jute and Jute-Cotton Fabrics.

Material to Liquor Ratio	Mateiral Type	Pyrovatex CP New Concentration (% owf)	Flame Spread Time (sec)	After Glow Time (sec)	Char Length (cm)
1:10	Jute	0	21.67 (±1.1)	14.66 (±1.1)	15
		50	0	0	2.73 (±0.6)
		60	3 (±2.6)	1.67 (±1.5)	2.7 (±0.3)
		70	0.33 (±0.5)	0	2.8 (±0.5)
		80	0	0	2.7 (±0.1)
		90	0	0	2.63 (±0.7)
1:07	Jute	0	21.67 (±1.1)	14.66 (±1.1)	15
		50	0	1 (±0.5)	2.93 (±0.1)
		60	0	0	2.8 (±0.5)
		70	0	0.17 (±0.2)	2.76 (±0.3)
		80	0	0.33 (±0.2)	2.73 (±0.1)
		90	0	0	2.2 (±0.2)
1:05	Jute	0	21.67 (±1.1)	14.66 (±1.1)	15
		50	0	0	2.86 (±0.4)
		60	0	0	2.97 (±0.1)
		70	0	0	2.47 (±0.4)
		80	0	0	2.4 (±0.4)
		90	0	0	2.43 (±0.6)
1:07	Jute-Cotton	0	28 (±1.7)	17.67 (±0.5)	15
		50	0	0	2.93 (±0.1)
		60	0	0	2.97 (±0.1)
		70	0	0	2.9 (±0.1)
		80	0	0	2.83 (±0.05)
		90	0	0	2.73 (±0.1)

According to the results extracted from Table 1, the flame-retardancy property appeared to be improved significantly in all the treatment baths as well as at all the concentrations. However, comparing among three liquor ratios, the least flame spread time, afterglow time, and char length was found in a 1:7 liquor ratio bath. Although the flame spread time and afterglow time for all the treated baths remained almost zero, there are some remarkable differences found on char length. Among all treatment baths, the least char length (2.2 cm) was measured in the 90% (owf) FR treated Jute fabric in a 1:7 material-to-liquor ratio, while it was counted as 2.73 cm char length on Jute-Cotton fabrics treated under the same conditions. Furthermore, the entire length (15 cm) of the untreated fabrics was burned within the flame spread time of 21 seconds and 28 seconds for the Jute and Jute-Cotton fabrics, respectively. The vertical flammability results reported in this study show significant improvement in flame-retardance in the Jute-based materials used in this study.

Physio-mechanical properties analysis

The extent of physio-mechanical damage was determined through the loss of tensile and tear strength and elongation at break measurements. Fig. 1 shows the properties of tensile strength, tear strength and elongation at break in the warp and weft directions of Jute and Jute-Cotton fabrics. It can be observed from the figure that the tensile strength decreased in the FR treated fabrics compared to that of the untreated for warp and weft directions of Jute fabrics. A higher trend of strength loss is observed in the warp direction of the FR-treated jute-cotton fabrics, while negligible strength loss was reported in the weft direction on the same fabric. These results correspond to a greater strength loss in Jute than in cotton by flame-retardant treatment since a negligible strength loss was found in the weft direction of the Jute-Cotton fabric. Similarly, tear strength loss was determined on the FR treated Jute fabrics in both warp and weft directions. Though the strength loss trend remains almost similar as tensile, however, more loss was reported in the weft direction than in the warp. On the other hand, a notable loss of tear strength was observed in the warp direction of the Jute-Cotton fabric after FR treatment, and a slight deterioration was observed in the weft direction of the same fabric. Such findings on the loss of physio-mechanical properties are justified by the earlier study as well [12].



	Warp - Tensile Force (N)	Weft Tensile Force (N)	Warp Tear Force (N)	Weft Tear Force (N)	Warp Elongation (%)	Weft Elongation (%)
FR Treated Jute-Cotton	463.97	179.0933333	25.31666667	10.26333333	5.215666667	44.26333333
Untreated Jute-Cotton	679.3833333	191.8	31.43666667	11.73	6.86	49.21
FR Treated Jute	228.7366667	216.3133333	34.17666667	33.64	16.44	18.88
Untreated Jute	294.2066667	272.6633333	38.07666667	43.53333333	21.76	21.49333333

Figure 1. Tensile Strength, Tear Strength and Elongation at Break of Jute and Jute-Cotton Fabrics ((M:L:1:7, Pyrovatex CP New: 90% owf)).

It was observed that a downward trend of elongation resulted in FR treated fabrics in both warp and weft directions of Jute and Jute-Cotton fabrics. However, the least elongation resulted in the warp direction of the FR-treated Jute fabrics than in the weft direction. Consequently, in the Jute-Cotton fabrics, although the elongation loss was similar as in the Jute fabrics, the higher elongation at maximum force can be observed in the weft direction on both treated and untreated fabrics. This can be due to the variances of yarn that is used in both directions. Compared to the untreated one, though there was a slight loss of elongation on the warp direction of the FR treated Jute-Cotton fabric. The technical reason behind this lower elongation at break on untreated and treated fabric can be due to higher twisted cotton yarn that shows lower elongation on the warp direction than that of Jute in the weft.

CONCLUSION

The present study investigates the possible opportunity to improve the flame-retardancy property of jute and jute-cotton fabric by using a commercially available flame-retardant chemical. The burning nature of both fabrics improved significantly on both FR-treated fabrics compared to their initial burning condition. The entire untreated sample (15 cm) was burnt in less than 30 seconds (flame spread time after ignition time) while it counted zero second to get a char length of 2.2 cm and 2.73 cm for Jute and Jute-Cotton fabrics, respectively. FR treated fabrics showed remarkable loss of tensile and tear strength compared to untreated fabrics in both warp and weft directions.

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