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Development of Fire Retardant on Jute by Chemical Means

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Abstract

Jute is highly flammable in character. Due to its high degree of flammability, the versatile use of this fibre is handicapped to some extent, particularly in some specific purpose where jute products with flame resistance finishes and demanded. Considering this disadvantage, a research project was undertaken to make this fibre flameproof and therefore safer in specialized textile uses. The study was performed using yarn and fabrics which were desized with diastase and lissapol-N. Yarn and fabrics were scoured with sodium carbonate, sodium hydroxide under some standard conditions. These pretreated yarns and fabrics were used in the whole experimental work. The treated yarns were tested for flame retardant by subjecting them to the luminous flame of Bunsen burner and by observing the time of flaming (after flame) and time of glowing (flameless combustion, after glow), if any Percentage losses of strength of the treated yarn and fabrics were also measured by standard method. Different solutions of fire resistant chemicals were prepared to change the chemical, concentration and pH ratio of the solution. Jute fabrics and yarns treated with 65% solution of urea and ammonium dihydrogen phosphate (the ratio of urea and ADP being 3:2) together with 2% Turpex NP and 3-6% perapret PE-40% were found durably flame retardant causing minimum loss of the strength. This research was focused on fire resistant treatment of jute yarn and fabrics with different chemicals to make jute products for diversified textile uses.

Keywords: Fire retardant, Desirable, Jute fibre, Jute fabric, finished products, Furnishing.

INTRODUCTION

Jute is a natural fibre composed of cellulose (58-635%), lignin (12-14%), hemicelluloses(21-24%), waxes and protein mineral matters [1-2]. The cellulosic textile materials have been practiced in different institute for a many years [3]. The major part of the research in this paper has been referred entirely to fibres other than jute, a highly flammable lignocelluloses material [4]. For its some specialized textile uses such as wall covering, furnishing fabrics, carpet and carpet backing cloth and other upholstery purposes, it is necessary to make jute fabrics fire retardant [5]. Flammability of fibrous products is one of the major problems posed to scientists and technologists at the present time [6]. A fire involving wear clothing appears to be the most dangerous and shows the highest rate of deaths per fire [7]. For promotions of uses of jute as protective textiles it can be made fire retardant. Jute fiber has good spin capacity and can be used in the textile sector for garments [8]. However, it burns easily and involves frequent fires. Jute cellulose undergoes decomposition during ignition, which produces highly explosive volatile compounds, mainly with the spread of laevoglucose fires that cause injuries and deaths in fire accidents [9]. As consumers are now increasingly aware of a safer lifestyle, the expectations and demand for diversified flame retardant jute products are constantly increasing. All fiber and textile products may be involved in starting of fires [10]. Many attempts were made by scientists to reduce fire hazards by introducing fire retardant treatment and suitable clauses in fabric specifications [11]. Demand for fireproof jute products is also increasing due to its long life cycle and increasing use in household textiles and furnishings [12]. Various chemical formulations have been reported for the preparation of flame resistant jute fibers and fabrics [13]. It has been found that various inorganic salts, borax-boric acid composition like sodium silicate, various phosphorus and nitrogenous compounds and their combinations are mostly used in making fire-resistant jute. In this work jute fibre and fabrics has

been subjected to different type of fire retardant treatment to get fire retardant jute based fibre and without undesirable loss of the tensile strength for diversified textile uses.

MATERIALS AND METHODS

The study was carried out from 1st July 2015 to 30 June 2020 in Chemistry Division, Bangladesh Jute Research Institute, Dhaka.

Materials

Raw jute yarn and fabrics were collected from Mechanical processing division of Bangladesh Jute Research Institute (BJRI). Most of the experimental works had been carried out in the Industrial Chemistry Laboratory, Chemistry Division, Bangladesh Jute Research Institute (BJRI), Dhaka and Applied Chemistry& Chemical Engineering Department of Dhaka University.

Chemicals

Flame retardant chemicals such as Ammonium Dihydrogen Phosphate (ADP), ($NH_4H_2PO_4$), Urea (NH_2-CO-NH_2), were obtained from local market in Bangladesh. Other essential chemicals particularly Sodium Carbonate (Na_2CO_3), Sodium Hydroxide (NaOH), Turpex NP and Perapret (PE-40) were procured from local market in Bangladesh. All reagents were laboratory grade and were used without further purification. The following recipes were used for the preparation of fire retardant materials from jute yarn and jute fabrics.

Recipe 1	Recipe 2	Recipe 3
Ratio of urea and ADP-2:1 Conc. urea and ADP-50% Conc. of Turpex NP -5% Conc. of Perapret PE-40 -5% P^H of the flame proofing sol^n 6-8 Liquor ratio -1:6 Temperature- 40^0C-45^0C	Ratio of urea and ADP-2:1 Conc.of the mixture of urea and ADP-60% Conc.ofTurpex NP -5% Conc.of Perapret PE40 -5% P^H of the flame proofing sol^n 6-8 Liquor ratio -1:6 Temperature - 40^0C-45^0C	Ratio of urea and ADP-3:2 Conc. of urea and ADP-60% Conc. of Turpex NP -5% Conc.of Perapret PE40-5% PH of the flame proofing solutions - 6-8 Liquor ratio -1:6 Temperature - 40^0C-45^0C

The pretreated yarn and fabrics of known weight were impregnated with the above stated solutions for 3-5 minutes ensuring 100% liquor pick up. The impregnated yarn fabrics were cured in the wet stage at different elevated temperature for different time period. The cured samples after cooling to room temperature were washed with water at room temperature to remove the extremely adhering and untreated chemicals, if any. The samples were then squeezed and finally dried. To study the durability of flame retardant of the treated yarns, some cured samples were immersed in tap water at room temperature for 1-1.5 hours and then squeezed and dried again. The treated yarns from each set of experiment were tested for flame retardant by subjecting them to the luminous flame of Bunsen burner and by observing the time of flaming (after flame) and time of glowing (flameless combustion, after glow), if any Percentage losses of strength of the treated yarn and fabrics were also measured by standard method.

Impregnation

Unmodified jute yarn and fabrics were firstly treated with aqueous solution of ammonium dehydrogenate phosphate and other chemicals with varying concentrations, liquor ratio and treatment time to obtain an optimum condition of application for the desired fire retardant. Some fabrics were treated with ammonium bromide solution were treated with phosphoric acid solution in two steps (Double bath process). Both ammonium bromide and phosphoric acid treatment was also performed in one step by impregnating the unmodified fabrics in a single bath process. All the treatment was performed at room temperature. It may be noted here that the pH of the flame retardant solutions was controlled by the addition of Ammonia. In all the cases the impregnated jute fabrics were mangled, dried at room temperature and then % add-on was determined.

Fire proofing test

The treated jute fabrics were tested for fire-retardant by measuring the ‘after flame’ and ‘afterglow’ period under vertical Bunsen burner flame in the following test procedure. Treated fabrics of specimen size 12.5 inch x 2 inch (warp wise) were suspended vertically in a fume chamber adjusting the lower edge of the specimen at 0.75 inch above the top of the Bunsen burner having a tube of 0.375 inch inside diameter. The luminous flame height was regulated to 1.5 inch. The flame was applied vertically in the middle of the lower end of the specimen for 12 seconds and then withdrawn and the durations of after flaming and after glowing were noted and the char lengths were measured.

Tensile strength test

The tensile strength of the treated yarn and fabrics were measured by constant rate of stress method in tensile strength tester, machine parameter were fixed at Gauge length = 8”, rate of traverse = 12 cm/min. Average were taken as its. A Tensile strength of the treated fabrics along with some untreated fabrics of specimen size 12.5 inch x 4 inch (warp wise) were

measured after conditioning them for 24 hours at 65° R.H. and 20°C temperature.

Storage test

Effect of storage on the flame proofness and tensile strength of the treated fabrics were observed up to a period of six months.

Padding process

All chemicals with different concentrations were applied to both yarn and cloth. The padding baths of a two-bowl horizontal padding machine were used to pour the prepared solution and the fabric was impregnated to make it 100% wet. The pressure was set to 0.2 MPa and the bowl rotation was 20 m^{-1} to get the 95% pick up. For better results each sample was passed two times through a padding bath. After padding, the samples were dried using a stenter machine at a temperature of 100°C for 2 min. The pick-up percentage was calculated by using the following equation.

$$\text{Pickup (\%)} = \frac{\text{Wet weight of sample (g)} - \text{Dry weight of sample (g)}}{\text{Dry weight of sample (g)}} \times 100$$

RESULTS AND DISCUSSION

A fabric is regarded as flame proofed if it provides no after flame period, less than 4 seconds afterglow period and char length less than 3.5 inches by vertical Bunsen burner flame test. After flame is the time in seconds for which the fabric flames after the source of flame has been removed. After glow is the time in seconds for which the fabric glows after all flaming has ceased. Char length is the furthest distance of the damage caused by flaming or by glowing as measured from the lower edge of the vertically suspended fabric strip.

Different solutions of fire resistant chemicals (Conc. urea and ADP-50%, Conc. of the mixture of urea and ADP-60%, Conc. of Turpex NP-5%, Conc. of Perapret PE-40-5%) were prepared to change the chemical, concentration and pH ratio of the solution. The pretreated jute yarns and fabrics were treated with these solutions, cured in various conditions and the treated yarns and fabrics were tested according to standard test method for flame retardant and strength reduction of yarns and fabrics [14]. Jute yarns and fabrics can be considered flame-retardant if applied to the yarn for about 2 seconds after the bright flame of the Bunsen burner has been removed; the yarn does not burn for a second and does not continue for more than 2 seconds. During the experiment, the ratio of urea and ADP in the mixture of scattered chemicals was taken as 2: 1; the concentration of the solution was 50% and the impregnated yarns were cured while wet at 175°C - 185°C for 2 to 4 minutes. Although treatments have been found to give the yarn the desired flame resistance properties, it reduces the excess strength (about 36%) of the yarn as shown in Table 1. The yarn with a 50% solution of urea and ADP in a 2: 1 ratio failed to give the yarn complete flame resistance properties although strength loss occurred within 28% (Treatment No. 8). Table 2 shows that jute yarn treated with 60% urea and ADP solution in a 2: 1 ratio and in some cases can give the yarn almost complete flame resistance properties resulting in 29% strength loss (Treatment No. 8). Table 3, on the other hand, shows that jute yarn is 60% soluble in urea and ADP 3: 2 ratios, with some finishing additives, close to pH 7, 110% pick-up and curing for 2 to 4 minutes in wet condition at about 175°C - 185°C. The yarns can provide the desired flame resistance properties (flame after zero seconds, after 2 seconds) by reducing the strength by up to 30% (Treatment No. 8 and 9). A fabric is considered flame proof if it does not provide after a flame period, less than 4 seconds after glow period and vertical Bunsen burner flame test with a length of less than 3.5 inches. The second flame is the flame after which the fabric flame source has been removed. Afterglow is the time during which the fabric burns, after all, by measuring from the bottom edge of the vertically suspended fabric strip. From Table 4, it is observed that in the case of dry stage curing with the increase of concentration of perapret PE-40 (up to 6% concentration) in the flame proofing solution, the treated fabrics show the desired flame resistance property with minimum loss of fabric strength. From the above observations, it may be concluded that on treating with 65% solution of urea and ammonium dihydrogen phosphate (the ratio of urea and ADP being 3:2) together with 2% Turpex NP and 3-6% perapret PE-40% at pH 7 having 110% liquor pick up and with curing at 110°C -130°C for 3 to 12 minutes. Jute fabrics

can be made durably flame retardant causing minimum loss of the fabric strength (treatment no.8). However, although the treatment as developed can provide the desired flame retardant result but is not sufficiently fast to wash. It is observed that on storage of the treated yarn and fabrics the effect of flame proofed is not appreciably impaired and there is a gradual slight loss of tensile strength.

Hussain and co-workers worked on "Burning behaviour of phosphorylated jute" (5). They reported that flame retardancy test of treated jute fabric found significantly flame retardant with good fastness to washing. Basak and co-workers (11) evaluated flame retardancy of the fabric by Limiting Oxygen Index (LOI) and burning behaviour under vertical flammability tester including the char length. Burning rate was found to decrease by almost 10 times after an application of 2% SMSN (Sodium metasilicate nonahydrate) compared to the control sample. *Samanta and co-workers (6)* described the use of alum, borax and vitriol to prevent the flaming of paper, pulp or textiles. Different fire-retardant chemicals act in different way by manipulating pyrolysis, prevention of flammable gases, less or more char formation, controlling combustion, protecting/ preventing generation of flammable gases or from heat/oxygen and fuel to combat burning/propagation of flame (7,8,9). Our proposed method was undertaken to find out a method of preparing flameproof jute fabric without undesirable loss of the tensile strength.

Table 1: Flame resistance property and loss of strength of jute yarn (Recipe 1)

Treatment	P^H	Curing Temp. ^0C	Curing time(min)	After flame (sec)	After glow (sec)	Loss of strength (%)
1	6.0	175	4	2.0	3.5	33.5
2	6.0	180	3	1.5	3.0	34.6
3	6.0	185	2	1.5	3.0	36.0
4	6.5	175	4	1.5	3.5	30.4
5	6.5	180	3	1.0	3.0	31.5
6	6.5	185	2	1.0	2.5	32.9
7	7.0	175	4	1.0	3.5	27.2
8	7.0	180	3	1.0	3.0	28.1
9	7.0	185	2	0.5	3.0	29.3
10	7.5	175	4	2.0	3.5	30.5
11	7.5	180	3	1.5	3.0	31.5
12	7.5	185	2	1.0	2.5	32.6
13	8.0	175	4	2.5	4.0	32.3
14	8.0	180	3	2.0	3.5	33.7
15	8.0	185	2	1.5	3.0	35.1

Table 2: Flame resistance property and loss of strength of jute yarn (Recipe 2)

Treatment	P^H	Curing Temp ^oC	Curing time (min)	After flame (sec)	After glow (sec)	Loss of strength (%)
1	6.0	175	4	1.0	3.5	34.4
2	6.0	180	3	0.5	3.0	35.6
3	6.0	185	2	0.5	2.5	37.0
4	6.5	175	4	0.5	3.0	31.3
5	6.5	180	3	0.0	2.5	32.4
6	6.5	185	2	0.0	2.5	33.8
7	7.0	175	4	0.5	3.0	28.2
8	7.0	180	3	0.0	2.5	29.1
9	7.0	185	2	0.0	2.5	30.1
10	7.5	175	4	1.0	3.5	31.5
11	7.5	180	3	1.0	3.0	32.5
12	7.5	185	2	0.5	2.5	33.6
13	8.0	175	4	2.0	3.5	33.2
14	8.0	180	3	1.5	3.0	34.6
15	8.0	185	2	1.0	3.0	36.1

Table 3: Flame resistance property and loss of strength of jute yarn (Recipe 3)

Treatment	pH	Curing Temp °C	Curing time (min)	After flame (sec)	After glow (sec)	Loss of strength (%)
1	6.0	175	4	1.0	3.0	35.5
2	6.0	180	3	0.5	2.5	36.6
3	6.0	185	2	0.5	2.5	37.0
4	6.5	175	4	0.5	2.5	32.4
5	6.5	180	3	0.5	2.5	33.6
6	6.5	185	2	0.0	2.5	34.3
7	7.0	175	4	0.0	2.5	29.2
8	7.0	180	3	0.0	2.0	30.2
9	7.0	185	2	0.0	2.0	31.3
10	7.5	175	4	0.5	3.0	32.5
11	7.5	180	3	0.5	2.5	33.5
12	7.5	185	2	0.0	2.5	34.6
13	8.0	175	4	1.0	3.5	34.3
14	8.0	180	3	0.5	3.0	35.7
15	8.0	185	2	0.5	2.5	37.2

Table 4: Flame resistance property and loss of strength of jute fabrics

No. of treatment	Conc. of perapret PE-40 (%)	Curing Temp. °C	Curing time (min)	Vertical Bunsen burner flame test		Loss of strength (%)
				After flame (sec)	After glow (sec)	
1	3	110	12		0	35.6
2	3	120	5	0	0	33.7
3	3	130	3	0	0	33.8
4	4	110	12	0	0	33.6
5	4	120	5	0	0	32.7
6	4	130	3	0	0	31.8
7	5	110	12	0	0	33.6
8	5	120	5	0	0	31.6
9	5	130	3	0	0	33.8
10	6	110	12	0.5	0	32.0
11	6	120	5	0.3	0	30.1
12	6	130	3	0.3	0	29.1

Conflict of interest: The authors declare no conflict of interest.

CONCLUSION

The versatile use of this fiber is somewhat handicapped, especially for certain purposes where flame resistance ends up in jute products and there is a demand. Considering this difficulty, a research project was undertaken to make this fiber safe in the use of flameproof and specialized textiles. Developments of jute product finishing process were carried out by studying the possible use of textile finishing materials in jute products for specific end use. In this research paper we have focused on fire resistant treatment of jute yarn and fabrics with different chemicals for making fire resistant jute yarn and fabrics to make jute products for fabrics, decorative wall coverings, garments, carpets and carpet backing fabrics. Further work is going on to develop more durable fire retardant on jute and jute products.

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