Retention of Urea-Formaldehyde Resin Finish on Cellulosic Fabric and its Effect on Water Absorbent Capacity of the Treated Fabric

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ABSTRACT

Cellulosic (cotton) fabric was treated by immersion in 50.8% solid urea-formaldehyde (U-F) resin synthesized at 25°C, 40°C, 50°C, 60°C, 70°C, 80°C and 100°C. The resin retention and its effects on the water absorbent capacity of the treated fabric at these temperatures and one atmosphere were studied. The results showed that the retention of the U-F resin on cotton fabric increased with the synthesis temperature until a maximum retention of 1.93% at 70°C. The water absorbent capacity decreased as the synthesis temperature increased. For U-F resin synthesized at 70°C with the same solid content, it was observed that the water absorbent capacity decreased as the time of immersion of the treated fabric in water increased. It was then concluded that U-F resin finish synthesized at 70°C at 50.8% solid content and used in treating cotton fabric at the same temperature for a minimum of 25 seconds effectively decreased the water absorbent capacity of the hydrophilic cellulosic fabric, thereby improving its water repellency.

Keywords: Cellulosic fabric, urea-formaldehyde resin absorbent capacity, hydrophilic, water repellency.

INTRODUCTION

Fabric finishing is the treatment given to textile materials to make them suitable for specific applications. After cellulosic (cotton) fabrics have been woven, they are usually washed, bleached, mercerized, dyed or printed. Their appearance is finally improved by finishing operations, which may be physical or chemical. At one time the finishing included stiffening with starch and gums, weighting with clays and metal salts, drying to width and pressing or calendaring the fabric to provide a smooth glossy surface [1]. Although, these processes are still used today, modern advances in textile chemistry have introduced an entirely new group of textile finishes. The group includes amino resins such as urea formaldehyde (U-F) and melamine formaldehyde, which can be formed, or cured in the fabric while the fabric is held, extended, carefully folded or pressed firmly between two smooth surfaces. Amino resin finishing in cotton makes the fabric stable, crease resistant and water repellent.

Urea formaldehyde (UF) resin is an opaque thermoset resin produced by heating urea and formaldehyde in a solution of ammonia or pyridine. It is the most prominent examples of the class of thermosetting resins usually referred to as amino resins [2]. The resin is widely used as a moulding material and component of adhesives and protective finishes [2].The fiberboard industry is a large consumer of urea formaldehyde resin where it is used as a binding agent. Despite its many positive attributes, the resin does have one drawback in its release of formaldehyde gas under certain conditions. Urea formaldehyde resins are available as viscous liquids or as spray dried powders which require the addition of water prior to use. Formaldehyde resins are extremely tough, scratch resistant polymers which lend themselves ideally to a host of domestic and industrial applications. Urea formaldehyde resin possesses excellent tensile strength, flexibility, and heat distortion resistance; when cured, it forms a very resilient finish. These characteristics have made the polymer a useful additive to a wide range of products such as wood finishes, adhesives, and binding agents.

U-F resin is colourless and it can readily form emulsion in water for easy application. It can cross-link the cotton fibres and hence reduces the number of fibrils generated in the construction and washings of the material. Resin–treatment is widely used in textiles to improve crease–resistance of the fabrics and achieve easy–care properties [3]. The reactivity of the resin system is mainly dominated by the catalyst and curing temperature [2].

However, the methods and conditions of its application are still being investigated to improve a specific property requirement of the textile. Effect of pH on the Properties of Urea Formaldehyde Adhesives has been reported [4]. Physiological investigation of resin-treated fabrics from tencel and other cellulosic fibres have been investigated [5]. The Study of Water Behavior in Regenerated Cellulosic Fibres by Low–Resolution Proton NMR has been reported [6].

Amide-containing biopolymers and sludge from pulp mills can be added during the synthesis of UF resin to decrease the emission of free formaldehyde [7, 8]. The effect of UF resin adhesive modified EPU, $_{P}$MDI, and melamine-bridged alkyl resorcinol to the internal bonding strength and HCHO emission were studied [9, 10, 11, 12].

In order to make cotton fabrics suitable for application, especially in the wet regions of the world there is need to improve its water repellency under specific conditions. In this study, the suitable temperature to prepare the U-F resin cotton finish, the appropriate impregnation temperature, the minimal impregnation time to give the fabric optimal retention and reduce its water absorbent capacity were determined.

MATERIALS AND METHODS

All the reagents used were bought from the chemical stores. Standard measuring instruments were also used. The cotton fabric (calico) was obtained from Aba textile mill.

Urea formaldehyde resin finish was prepared by condensation of urea and formaldehyde at the synthesis temperatures of 25^oC, 40^oC, 50^oC, 60^oC, 70^oC, 80^oC and 100^oC. The average solid content was determined by heating the same weight of each emulsion to evaporate all the solvent. The cotton fabric was impregnated with U-F resin by immersion in 50.8% solid aqueous emulsion and cured at 100^oC. Retention of U-F resin on the cotton fabric samples was determined by gravimetric method. The water absorbent capacity determination was done by immersing a piece of cotton fabric in water for 15 seconds and the amount of water absorbed obtained by the difference in weight while the water absorbent capacity was calculated according to the method of Robert *et al.* [13].

RESULTS AND DISCUSSION

All the resin emulsions prepared were grayish white, syrupy liquids at 50.8% solid content. The resin retention on cotton fabric was generally high.

Effect of temperature on percentage retention and water absorbent capacity of UF-resin is presented in Table 1 and illustrated in Fig 1. There is a generally increase in percentage retention of the U-F resin on the cotton fabric as the synthesis temperature increased until after 70^oC at a retention (1.93%), it became irregular. On the other hand, the water absorbent capacity decreased as the synthesis and impregnation temperatures as the retention increased. The water absorbent capcity of 0.75 caused by retention of the resin synthesized at 70^oC was quite low indicating that the fabric was quite resistant to water penetration at that temperature. The effect of this has been discussed by Firgo, *et al*, [14].

Equilibrium retention occurred after 30 seconds, the water absorbent capacity (Fig. 2) as usual decreased as the retention increased. From these curves, it is necessary to impregnate the cotton fabric in the U-F resin emulsion for at least 25 seconds for it to have good retention for effective water repellency.

Table 1: Effect of temperature on percentage retention and water absorbent capacity of U-F treated cotton fabric.

Temparature (^oC)	Percentage Retention	Water Absorbent Capacity
25	0.70	1.3
40	1.30	1.1
50	1.67	0.90
60	1.70	0.80
70	1.93	0.75
80	1.85	0.72
90	1.75	0.71
100	1.80	0.70

Table 2: Effect of impregnation time on the percentage retention and water absorbent capacity at 70^{o}C

Impregnation Time (s)	Percentage Retention	Water Absorbent Capacity
5	1.35	0.65
10	1.40	0.62
15	1.60	0.55
20	1.80	0.48
25	1.95	0.45
30	2.05	0.47
35	2.10	0.49

Fig. 2 shows the effect of impregnation time on the retention and water absorbent capacity of the cotton fabric impregnated with U-F resin synthesized at 70^{o}C. There was an increase in percentage retention as the impregnation time increased.

Fig. 3 shows that there was an initial decrease in water absorbent capacity as the time of immersion of the impregnated fabric in water increased until after 6 minutes the curve became sinusoidal indicating that some other properties between the cellulosic fabric and U-F resin had set in equilibrium water absorbent capacity has been attained.

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Table 3: Effect of immersion time on water absorbent capacity at70^{o}C

Immersion Time in water (min.)	Water Absorbent Capacity
2	6.5
4	4.5
6	3.5
8	4.5
10	3.0
12	2.5
14	2.0
16	3.5
18	3.0

The observed effects of U-F resin on cotton fabric can be explained by the chemistry of the U-F resin as illustrated below in Figures below.

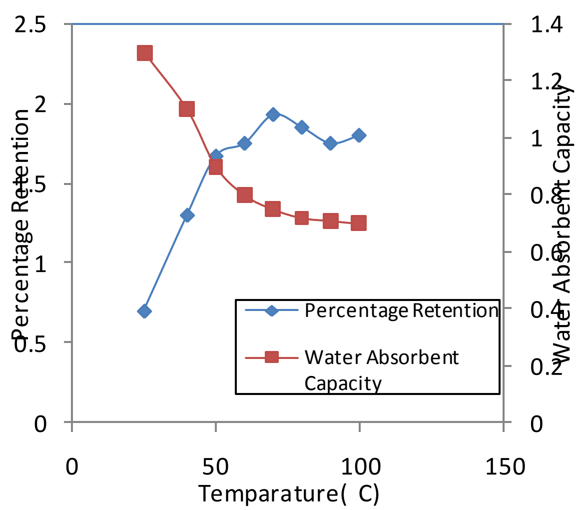

Fig.1: Variation of percentage retention and water absorbent capacity at 70^{o}C with temperature

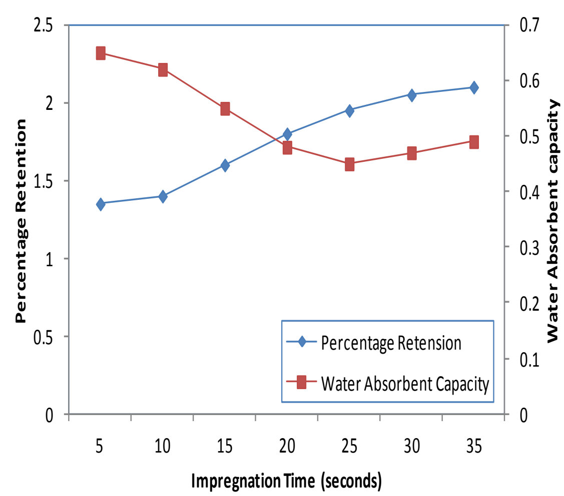

Fig. 2: Variation of percentage retention and water absorbent capacity at 70^{o} C with impregnation time.

In the course of the synthesis of urea-formaldehyde from urea and formaldehyde, the reaction takes place in two stages. First, the formation of monomethylol urea (I) and dimethyl urea (I0) occurs [15].

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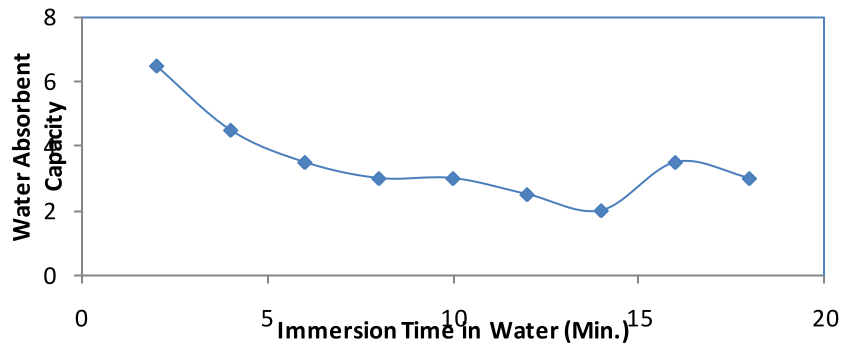
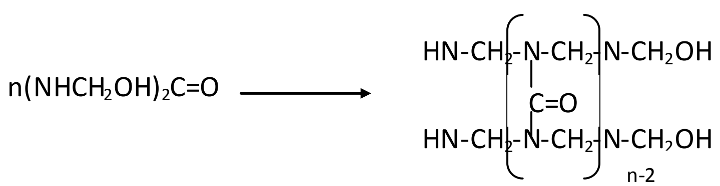


Fig 3. Variation of water absorbent capacity with immersion time

$$(NH_2)_2C{=}O \underset{}{\overset{CH_2O}{\rightleftharpoons}} \underset{(I)}{NH_2CH_2OH(NH_2)C{=}O} \rightleftharpoons \underset{(II)}{(NHCH_2OH)_2C{=}O} \quad \ldots\ldots\ldots\ldots \textbf{(a)}$$

Equation (a): Formation of Mono-(I), Dimethylolurea (II) by the addition of formaldehyde to urea

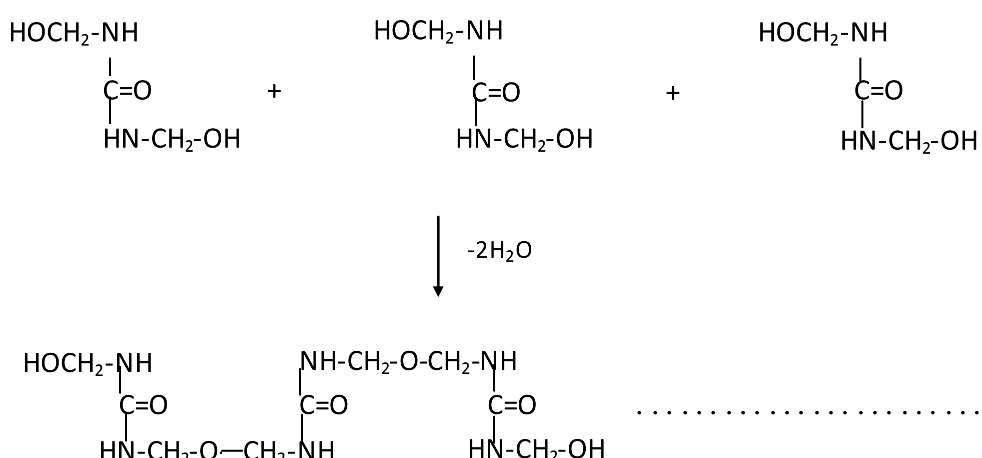
Usually, the products of reaction are not obtained from the solution in pure state; they form the precondensate containing about 50% of the main products [17]. At high temperatures and in the presence of catalysts in the system, the precondensate molecules impregnated in the fibre structure of the fabric are transformed into resin proper as shown in equations (b).



. . . . **(b)**

(III)

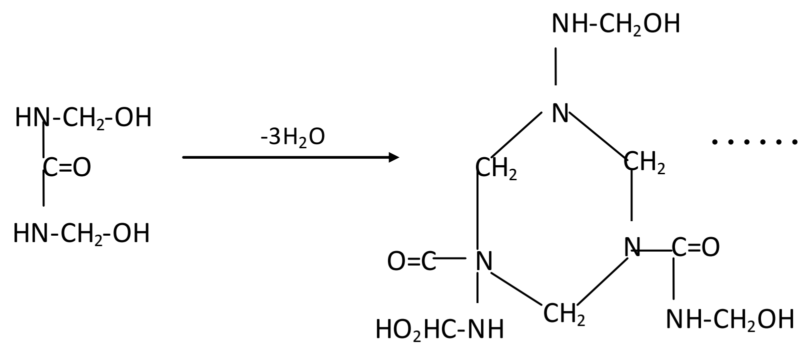
Equation (b): U-F Resin by formation of methylene bridges (III)



. . . . **(c)**

(IV)

Equation (c) U – F resin by precondensate molecules ether bond formation (IV)



.... **(d)**

(V)

Equation (d), U – F Resin cyclization and formation of Azomethine ring

In addition to these reactions, resulting in the formation of resin proper, i.e high molar mass compounds, the methylol derivatives of urea may react with the cellulose molecules to form covalent compounds as shown in equations (e).

$$\text{Cell-OH} + \text{HOH}_2\text{CNH-CO-NHCH}_2\text{OH} \xrightarrow{-H_2O} \text{Cell-O-CH}_2\text{NH-CO-NHCH}_2\text{OH}$$

$$\text{Cell-OH} + \text{HOH}_2\text{CNH-CO-NHCH}_2\text{OH} + \text{HO-Cell} \xrightarrow{-2H_2O} \underset{\text{(VI)}}{\text{Cell-O-H}_2\text{CNH-CO-NHCH}_2\text{–O-Cell}} \quad \ldots\textbf{(e)}$$

Equation (e): Covalent bond formation with cellulose

Besides the covalent bonds, the cellulose and methylol derivatives of urea may form H-bonds, in these way U-F resins react with cellulosic fibres and make them become more hydrophobic. By considering the chemistry of the U-F resin, high temperature should produce high molar mass U-F resin on the impregnated cotton fabric, at the same temperature and time, the U-F resin should soften and spread to fill the inter fibre openings in the fabric. Besides, reacting with the cellulose, the resin molecules can cross-link themselves in the fibre and form higher molar mass polymer that effectively coat and cover the surfaces of the cellulosic fibres in the fabric. Also the introduction of hydrophobic resin in the highly hydrophilic cellulosic fibres implies that absorption of water by the cotton fibres is now greatly hindered by the resin coating; thus, the water absorbent capacity of the impregnated fabric decreases while the water repellency improves (Fig. 1). This improvement in water repellency of the U-F resin impregnated cotton fabric is also experienced when U-F resin synthesized at a suitable temperature is used in impregnating cotton fabric for a long time i.e the longer the impregnation time, the higher the rentention and the lower the water absorbent capacity (Fig. 2). The decreases in water absorbent capacity with increases in the time of immersion (Fig. 3) is attributed to the swelling of the resin in water when it increases the surface area and effectively covers the cellulosic fibre surfaces, thus improving water repellency of the fabric. However after 6 minutes the sinusoidal nature of the curve should be due to adsorption and desorption of the water molecules on U-F resin unreactive surface that still contains some -OH groups that did not react with cellulose fibres.

CONCLUSION

The results of this study showed that the retention of urea-formaldehyde resin on cotton fabric samples increases with increase in synthesis and treatment temperature and with the impregnation time; in all cases the water absorbent capacity decreases as the resin retention and the immersion time increases.

In conclusion, the urea-formaldehyde resin for cotton fabric treatment should be synthesized at 70^{o}C at a solid content of 50.8% and the cotton should be impregnated in the resin emulsion for 25 seconds for optiomal retention; such treatment should give good water repellency characteristics to the cellulosic (cotton) fabrics which should be quite suitable for use in moist environment.

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