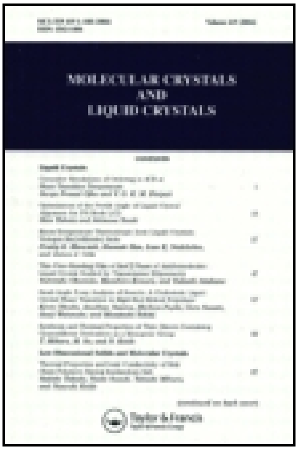

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Synthesis of Reactive Polymers and Their Applications to Cotton Fabrics as Permanent Size

Mohamed Hashem [a] & Ali Hebeish [a]
[a] National Research Centre, Textile Division, Dokki, Cairo, EGYPT

To cite this article: Mohamed Hashem & Ali Hebeish (2000): Synthesis of Reactive Polymers and Their Applications to Cotton Fabrics as Permanent Size, Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals, 353:1, 109-126

To link to this article: http://dx.doi.org/10.1080/10587250008025652

Mol. Cryst. and Liq. Cryst., 2000, Vol. 353, pp. 109-126
Reprints available directly from the publisher
Photocopying permitted by license only

Published by license under the
Gordon and Breach Science Publishers imprint.
Printed in Malaysia

Synthesis of Reactive Polymers and Their Applications to Cotton Fabrics as Permanent Size

MOHAMED HASHEM and ALI HEBEISH

National Research Centre, Textile Division, Dokki, Cairo, EGYPT

Dextrin was first polymerized with acrylamide. The so obtained polymeric hybrid was converted to a reactive hybrid through methylolation of its amide groups by reacting the latter with formaldehyde. On the other hand, poly(vinyl alcohol) was converted to a reactive form via its reaction with N-methylol-acrylamide in alkaline medium. The two polymeric materials were then applied to cotton fabric with a view to achieve two objectives. The first is to prepare cotton fabric bearing permanent size. The second is to make use of these polymeric molecules in chemical finishing of cotton. In both cases the application involves acid catalyst. Besides, the application was carried out under different conditions including type and concentration of catalyst, curing time and the concentration of the reactive polymeric material. The treated fabrics were monitored for strength properties, size add-on, and durability in addition to crease recovery in case of the finished fabric.

Keywords: Cotton; dextrin; finishing; polymer; sizing; textile

INTRODUCTION

The synthesis of reactive polymeric products and their application in textile sizing and finishing are of utmost importance[1]. The use of such reactive products as a substitute for temporary finishes or traditional sizes would contribute in improving the quality of the environment in addition to the economic impact. It is understandable that traditional sizes as well as temporary finishes are liable to washing and in so doing they increase the pollution load and detract from the properties of the fabric. On the other hand, the reactive polymeric substitutes react with the hydroxyl groups of cotton cellulose and become an integral part of the fabric.

The loom-finish state is sometimes desirable to enhance hand, wear characteristics, or weight (body). These features can be attained by employing a non-removable size. Many acrylate polymer sizes can be insolubilized by controlled crosslinking with appropriate catalyst[2]. An association complex of polyacrylic acid with polyethylene glycols has also been reported[3]. Insoluble sizes suitable for cellulosics have been obtained by reaction of starch with a solution of a triazine[4]. Similar results are obtained when aqueous solutions of poly(vinyl alcohol) are treated with 2-β-naphthoxy-4,6-dichloro 1,3,5-triazine in the presence of sodium bicarbonate[5]. Heating methacrylic acid monomer with poly(vinyl alcohol) at 90°C, 3-5 hr and deposite the products on cellulose, polyester or acrylic yarns, dried at 110-130°C yield insoluble size[6]. Poly(vinyl alcohol) can be crosslinked by controlled reaction with polycarboxylic acid[7].

In the finishing area, previous reports[8,9] have emphasized the use of poly(vinyl alcohol). Ability of the latter to improve wet recovery angle is associated with its ability to help water retention in the fabric structure at the time of chemical reaction, thereby reducing fabric wet stiffness and enhance fabric wet recovery.

The reaction of poly(vinyl alcohol) with N-methylolacrylamide in alkaline medium was recently reported[10]. The so obtained N-methylol-carbamoylethyl poly(vinyl alcohol) can be considered as reactive polymer. Also studied were done on the synthesis and characterization of a new polymeric products based on dextrin-polyacrylamide hybrid[11]. It was disclosed that this hybrid could serve as a good sizing agent by virtue of its excellent water solubility properties.

The present work is undertaken with a view: (a) to establish the optimum conditions for reacting N-methylolcarbamoylethyl poly(vinyl alcohol) (reactive PVA) and N-methylolated polyacrylamide-dextrin hybrid (reactive hybrid) with cotton cellulose; (b) to study the technical feasibility of these reactive polymers as permanent sizing agent; and (c) to examine the suitability of the said reactive polymers as reactive finishes which enhance fabric performance

EXPERIMENTAL

Materials

Dextrin

Four different types of dextrin, namely, Dextrin-85 (D-85), Dextrin-86 (D-86), British Gum (B.G) and White Dextrin (D.W), were kindly supplied from The Egyptian Starch and Glucose Manufacturing Company, Cairo, Egypt. Table I shows the properties of each type, as determined according to methods described elsewhere[11, 12].

TABLE I Properties of the types of dextrin used

Properties	D-85	D-86	B.G	D.W
Viscosity (mPa.s) of 10 % aqueous solution at 80°C and shear rate 516 s^{-1}	100	60	10	160
Water soluble matter (%)	65	85	50	30
pH	5	5	8.5	7.5
Moisture content (%)	6	5	5	7
Ash content (%)	0.15	0.11	0.15	0.08

Poly(vinyl alcohol)

Two types of poly(vinyl alcohol) (PVA) were kindly supplied by Firma Hoechst, namely, Vinarol®(ST) and Vinarol® (DT). Chemical analyses show that Vinarol®(ST) acquires apparent viscosity of 70 mpa.s and acetyl content[11] of 14 %. Whereas Vinarol®(DT) acquires apparent viscosity of 30 mpa.s and acetyl content of 14%.

Chemicals

Acrylamide, N-methylolacrylamide (48% aqueous solutions), ceric ammonium sulphate, sodium thiosulphate, ammonium chloride, ethanol, acetic acid, boric acid and sodium hydroxide were analytical grade chemicals. Egyptol (non-ionic wetting agent) was of technical grade.

Reaction of Poly(vinyl alcohol) with N-methylolacrylamide (Preparation of Reactive PVA)

Reactive PVA were prepared by reacting PVA with N-methylol-acrylamide in alkalin medium as described elsewhere[10]. The so obtained N-methylol-carbamoylethyl poly(vinyl alcohol) product was referred to reactive PVA.

Preparation of Polyacrylamide-Dextrin Hybrid

Polyacrylamide-dextrin hybrid was prepared as described elsewhere[1].

Methylolation of Polyacrylamide-Dextrin Hybrid (Reactive Hybrid)

Polyacrylamide-dextrin hybrid sample was methylolated as described in the reported method[14].

Reaction of Reactive PVA and Reactive Hybrid with Cotton Cellulose

10% aqueous solutions of the reactive polymers prepared as described above were cooked at 90°C. Cooking was carried out under continuous stirring. Ammonium chloride catalyst (2-20 g/l) was added during cooking. Strips (300×300 mm) of cotton fabric were impregnated in the cooked reactive polymer, then squeezed between two heavy rolls to a wet pick up of ca 100%. At this end, the sized strips were dried at 80°C for 5 min then cured at a temperature ranging from (120 to 180°C) for different lengths of time (2-6 min). Finally the samples were washed one time with hot water (60°C) and non-ionic wetting agent Egyptol (2 g/l) followed by washing with running water and drying at ambient conditions.

Sizing Process

The dextrin-polyacrylamide hybrid was dissolved in water to a concentration of 10% and the sample was mechanically stirred in a thermostat water-bath. The temperature was then raised from 25°C to 95°C in 30 min, keeping the rate of stirring constant at 150 rpm. Ammonium chloride catalyst (2-20 g/l) was added during stirring. Strips (5 × 300 mm) of light cotton fabric were impregnated in the heated hybrid at 90°C, then squeezed between two heavy rolls to a wet pick up of ca 100 %. At this point, they were dried at 80°C for 5 min and cured at (120-180°C) for (2-6 min). The samples were finally conditioned at 25°C and 65% relative humidity for at least 48 hours before testing.

Finishing Application

As in sizing application but in this case strips of cotton fabric (300 × 300 mm) were used.

Testing and Analysis

The nitrogen content was determined according to the microKjeldhal method[15].

The methylol content were determined according to the reported method[16].

The apparent viscosity of the heated hybrid samples (10 % aqueous solution) was measured by using a co-axial rotary viscometer (HAAKE RV 20) at 85°C and a shear rate of 516 s^{-1}.

Tensile strength and elongation at break of sized samples was tested according to ASTM methods[17].

Dry and wet wrinkle crease recovery angles were determined according to the standard method[18].

RESULTS AND DISCUSSION

Reaction of the Reactive Polymers with Cotton Cellulose

To start with, reaction of N-methylolpolyacrylamid-dextrin hybrid (reactive hybrid) and N-methylolcarbamoylethyl poly(vinyl alcohol) (reactive PVA) with cotton cellulose in presence of ammonium chloride as a catalyst was studied. The reaction was performed under different conditions including, temperature, catalyst concentration and curing time. Reactive PVA(ST) was used as the reactive polymer. Results obtained are discussed below. The extent of the reaction is expressed as percent nitrogen (% N).

Reaction Temperature

Figure 1 shows the effect of temperature on the extent of the reaction of reactive PVA(ST) with cotton cellulose, expressed as % nitrogen content. Obviously the extent of the reaction increases significantly by raising the temperature from 120°C to 160°C. Thereafter, the favourable effect of temperature ceases and a state of levelling off is achieved. A temperature up to 160°C seems to create the most appropriate environment for reaction of the N-methylol groups of the reactive PVA(ST) with the hydroxyl groups of cotton cellulose. It is likely that at 160°C the decomposition of NH_4Cl take place yielding HCl which further decomposes to yield the proton required for formation of carbonium ion on the N-methylol group of the reactive PVA(ST) thereby inducing reaction of the latter with the cellulose[19]. At a temperature higher than 160°C, decomposition of NH_4Cl proceeds very fast with the possibility that HCl is partly evolved without necessarily partici-pating in the catalysis. That is, the expected favorable effect of the catalyst at higher temperatures is outweighed by its partial evolution.

Ammonium Chloride Concentration

Figure 1 shows the effect of NH_4Cl concentration on the extent of the reaction occurring between reactive PVA(ST) and cotton cellulose. It is seen that the extent of the reaction, expressed as %N increases as the concentration of NH_4Cl increases from 2 to 8 g/l. Higher concentrations leave the extent of the reaction practically unaltered. This means that NH_4Cl at a concentration of 8 g/l brings into focus the best catalysis under the conditions used. The enhancement in the extent of the reaction upon increasing NH_4Cl concentration from 2 to 8 g/l could be explained on the immobility of the N-methylol group of PVA(ST). Conversion of these groups to the intermediate reactive carbonium ions is governed by the hydrogen protons in the vicinity of these groups; a state of affairs which is justified by increasing NH_4Cl molecules in the vicinity of the reactive PVA(ST).

Curing Time

Figure 1 illustrates also the effect of duration on the reaction of reactive PVA(ST) with cellulose at 160°C. The extent of the reaction is expressed as %N. As is evident the extent of the reaction is very poor when it was allowed to proceed for 2 minutes. On the other hand, substantial reaction occurs during 3 minutes duration and attains optimal after 4 minutes. Further prolongation of the reaction time exerts practically no effect on the extent of the reaction. This implies that 4 minutes-reaction time constitutes the best contact time among reactants. Longer duration is meaningless since no improvement in the extent of the reaction is observed thereof.

Utilization of reactive PVA and Reactive Hybrid as Permanents Sizes

Reactive polymeric products, namely, N-methylolcarbamoylethyl PVA (Reactive PVA) and N-methylolpolyacrylamide-dextrin hybrid (reactive hybrid) were prepared containing different methylol contents. These products were monitored for apparent viscosity as well as sizability. The latter was assessed through application of these reactive polymeric products to a gauze made of 100% cotton. The method adopted for application involved padding the gauze in an aqueous cooked sample of the reactive product (10% solid content) which contained NH_4Cl (8 g/l). Temperature of the cooked sample was kept at 90°C and padding was effected to ca 100% wet pick up. The so treated gauze was then dried in an air oven at 80°C for 5 minutes. The dried sample containing ca 10% add-on of the sizing material was thermally treated at 160°C for 4 minutes. The sample was finally conditioned at 65% relative humidity and 20°C for at least 48 h before testing for strength properties.

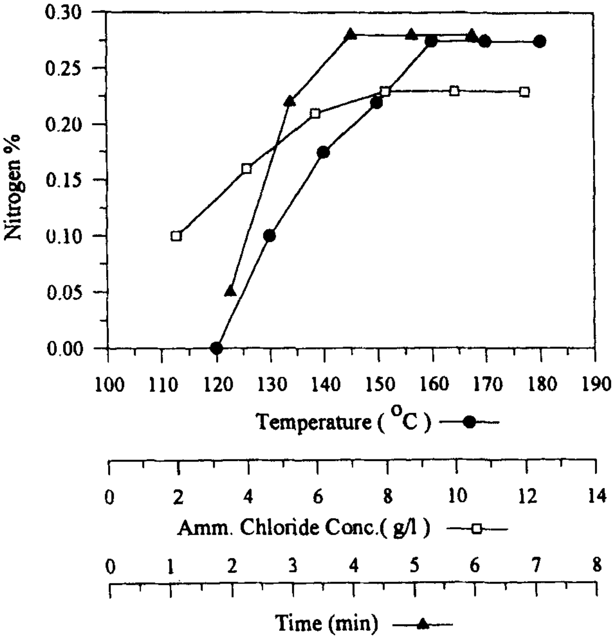

FIGURE 1 Effect of temperature, amm.chloride concentration and time on the reaction of reactive PVA(ST) with cotton cellulose.

Reactive Polymeric Products Based on PVA

Figure 2 shows the dependence of the apparent viscosity and sizability of reactive PVA(ST) on the % methylol of the latter. The results signify that the apparent viscosity is directly related to % methylol; that is the apparent viscosity increases as the % methylol increases; tensile strength of the gauze also increases after sizing with reactive PVA(ST) having 0.5% methylol. Higher % methylol tends to decrease the tensile strength but with the certainty that the sized gauze exhibits much higher tensile strength than the unsized gauze. On the other hand, the elongation at break of the gauze decreases after sizing and decrease is higher the higher the % methylol.

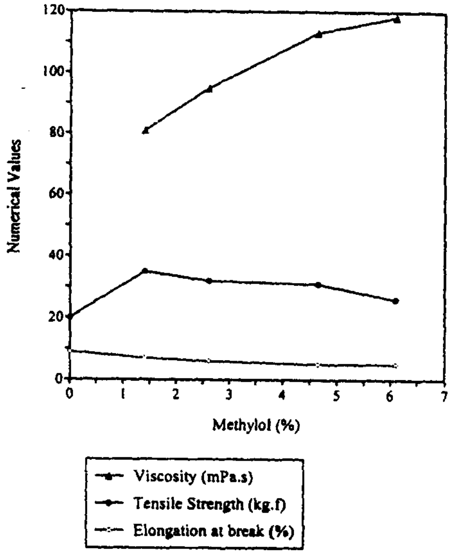

FIGURE 2 Dependence of the apparent viscosity and sizability (tensile strength and elongation at break) of reactive PVA(ST) on its methylol content. 0 % methylol content represent the untreated fabric

The enhancement in apparent viscosity by increasing the % methylol of reactive PVA(ST) could be ascribed to the introduction of the bulky methylol groups in the molecular structure of carbamoylethyl PVA(ST). On the other hand, improvement in tensile strength is a direct consequence of the extra strength conferred on the gauze by the size film. Meanwhile the tendency of tensile strength to decrease when reactive PVA(ST) with higher methylol contents were used calls for crosslinking and factors associated with such as rigidity and molecular degradation of the cotton gauze. Indeed the substantial reduction in elongation at break, particularly at higher % methylol is in full agreement with this postulation.

Figure 3 shows the dependence of apparent viscosity and sizability (expressed as tensile strength and elongation at break) of reactive PVA(DT) on the % methylol. The results feature that the apparent viscosity increases by increasing the % methylol of the reactive PVA(DT). The tensile strength increases after sizing but this increase relies on the % methylol, it is lower the higher the % methylol. On the other hand, the elongation at break decreases as the % methylol of reactive PVA(DT) increases. This is rather the trend observed above with reactive PVA(ST) and could be explained on similar basis.

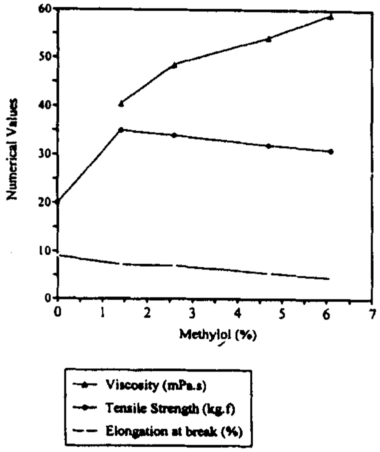

FIGURE 3 Dependence of the apparent viscosity and sizability (tensile strength and elongation at break) of reactive PVA(DT) on its methylol content. 0 % methylol content represent the untreated fabric

A comparison between the results of figure 3 and those of figure 2 would conclude two main points. First, at the same % methylol, the tensile strength of gauze sized with reactive PVA(DT) is higher than that sized with reactive PVA(ST). Second the values of the elongation at break of both sized gauzes are comparable. This reflects the contribution of the molecular weight of PVA during its chemical modification and the onset of this on the film forming properties which, in turn, are reflected on its sizability. Current date disclose that reactive PVA(DT) with its lower molecular weight serve as a better permanent size than PVA(ST) with its relatively greater molecular weight.

Reactive Polymeric products Based on Polyacrylamide-Dextrin Hybrid

Reactive polyacrylamide-dextrin hybrid was prepared by methylolation of polyacrylamide-dextrin hybrid with formaldehyde. Different types of dextrin were used in the preparation of the reactive hybrid, namely, dextrin 85 (D-85), dextrin 86 (D-86), white dextrin (D-W) and British Gum (B.G). Reactive hybrids containing different % methylol were prepared from each of these dextrins. These reactive hybrids were assessed for apparent viscosity and sizability in a manner similar to that used in case of reactive PVA as indicated above. The results obtained are set out in table II.

It is seen (table II) that the apparent viscosity decreases as the % methylol increases, unlike reactive polymeric products based on PVA. This suggests that the reactive hybrid, particularly the dextrin component, undergoes hydrolytic degradation during the cooking operation thereby decreasing the molecular weight and, therefore, the apparent viscosity. That is dextrin, regardless of its type, seems to be susceptible to hydrolysis under the effect of formic acid (brought about by methylolation followed by oxidation) and heat. With respect to sizability, the improvement in tensile strength is inversely related to the apparent viscosity of dextrin; the lower the apparent viscosity the higher the tensile strength. This is not the case with the elongation at break where no clear-cut relation exists between this property and type of the reactive hybrid which, in turn, is decided by the type of dextrin used. It is further noted that like reactive PVA, the improvement in tensile strength of gauze sized with reactive hybrids decreases as the % methylol increases.

TABLE II Application of reactive hybrid as sizing agent

Type of Dextrin	Graft Yield (%)	N (%)	Methylol (%)	Viscosity (mpa.s)	Tensile Strength (Kg.f)	Elongation at break (%)
Untreated Sample	-	-	-	-	17	7
D-W	50	6.6	0.5	91.5	23.8	5
			1.0	84	20.3	5.5
			1.5	77	18.5	6.5
D-85	65	7.8	0.5	82	20	6.5
			1.0	75	28	7
			1.5	70.3	25	5.5
D-86	100	9.2	0.5	81	27	5
			1.0	72.1	30	5.5
			1.5	68.3	28	5
B.G	100	9.2	0.5	60	32.5	5
			1.0	50	20.5	5.5
			1.5	46.2	18.5	6.5

Utilization of Reactive PVA and Reactive Hybrid as Finishing Agent

Figures 4A and 4B depict the dependence of the fabric performance, measured as tensile strength, elongation at break and dry and wet wrinkle recovery angles, on the % methylol of reactive PVA(ST) and reactive PVA(DT) respectively. The cotton fabric was treated with the two reactive polymers independently according to the conventional pad-dry-cure technique as described in the experimental section. It is observed that finishing treatment of the cotton fabric with the two polymeric products under investigation enhances considerably the fabric performance. This is evidenced by the substantial improvement in the tensile strength and the outstanding augmentation in dry and wet crease angle though the latter is significantly higher than the former. Meanwhile the adverse effect of % methylol on elongation at break and on the improvement in tensile strength is not so striking.

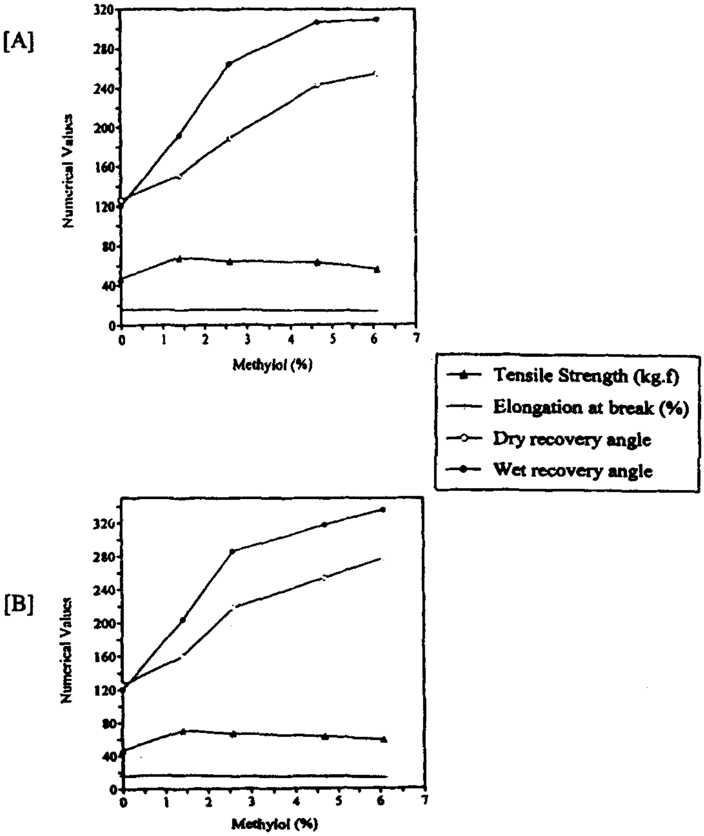

FIGURE 4 Relation between the methylol content in the reactive PVA and its viscosity, tensile strength and elongation at break of the cotton fabric.

0 % methylol content represent the untreated fabric.

FIGURE 4A, Reactive PVA(ST); FIGURE 4B, Reactive PVA(DT)

Enhancement in dry crease recovery by increasing the % methylol imply that considerable crosslinking occurs while the cotton cellulose is in the collapsed state. The situation is more aggravated and significant. Fibre stabilization occurs while the cotton cellulose in the swollen state via crosslinking or "in situe" deposition of polymeric network brought about by self-reaction of the reactive polymer molecules or single-ended reaction of the latter with cotton cellulose or all the three types of reaction. The ability of these reaction products to help water retention in the fabric structure during the chemical finishing would certainly diminish fabric wet stiffness and, as a result, augments wet crease recovery.

A comparison of the results of figure 4A with those of figure 4B would reveal that at the same % methylol, fabric treated with reactive PVA(DT) exhibits higher wet and dry crease recovery than that treated with reactive PVA(ST). The lower molecular weight of PVA (DT) than PVA(ST) may account for this. Reactive PVA(DT) by virtue of its lower molecular weight penetrate the fibre structure more easier than does reactive PVA(ST). Once this is the case, crosslinking polymeric network formation and/or attached PVA(DT) resulting from the single ended reaction of reactive PVA(DT) with cotton cellulose would take place in the interior of the fibre structure thereby inducing fibre stabilization and enhancing wet and dry crease recovery. The situation is different in case of reactive PVA(ST) which due to its high molecular weight the said reactions would take place largely on the fabric surface and hence, lower fibre stabilization as compared with PVA(DT).

Table III shows the fabric performance when cotton fabric was treated with different reactive polymeric products based on dextrin. The results feature that irrespective of the type of dextrin used in preparation of the reactive polymer, the wet and dry crease recovery increases of by increasing the methylol content from 0.5 to 1%. Further increase in the % methylol to 1.5% is accompanied by decrement in wet and dry crease recovery. Higher % methylol seems to favour occurence of polymeric network formation through self-reaction of the reactive dextrin molecules rather than crosslinking. It is understandable that the latter is more effective in enhancing crease recovery than the former.

The dependence of tensile strength and elongation at break on the % methylol follows a trend which is similar to the trend discussed above for the crease recovery. On the other hand at the same % methylol the dry and wet crease recovery follows the order:

B.G > D-86 > D-85 > W.D >> Blank sample

Whereas the tensile strength has the order

D.W > D-85 > D-86 > B.G >> Blank sample

These orders reflect the onset of the molecular weight of dextrin on the mode of interaction of the reactive dextrin products with cotton cellulose.

TABLE III Application of reactive hybrid as finishing agent

Type of Dextrin	Graft Yield (%)	N (%)	Methylol (%)	Viscosity (mpa.s)	Tensile Strength (Kg.f)	Elongation at break (%)	Dry CRA* (W + F) (Degree)	Wet CRA (W + F) (Degree)
Untreated Sample	-	-	-	-	47	16	126	120
D-W	50	6.6	0.5	91.5	60	15.5	198	240
			1.0	84	58	15	249	294
			1.5	77	60	13	209	260
D-85	65	7.8	0.5	82	60	15	230	285
			1.0	75	53	14	266	305
			1.5	70.3	53	14	262	292
D-86	100	9.2	0.5	81	60	15.5	233	198
			1.0	72.1	52	14	282	325
			1.5	68.3	55	13	247	311
B.G	100	9.2	0.5	60	54	14	277	319
			1.0	50	55	13.5	283	328
			1.5	46.2	58	13	280	318

* CRA (W + F) = Crease Recovery Angle, Warp direction + Weft direction

Durability of Reactive PVA and Reactive Hybrid

Cotton fabric samples, which were treated with reactive PVA and reactive hybrid, were subjected to several washing cycles with water using 2 g/l non-ionic wetting agent at 60°C for 15 min. After each cycle, change in % nitrogen was determined. Results obtained with each type of reactive polymer along with its methylol content and the change in % N are set out in table IV.

TABLE IV Durability of the reactive polymers on the finished fabric

Type of reactive polymer	Methylol %	% Change in the nitrogen content *				
		Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5
D.W	1.5	79.8	70.1	65.3	62.1	60.5
D-85	1.5	92.6	90.8	87.9	86.2	85.5
D-86	1.5	95.8	91.7	90.3	88.9	88.2
B.G	1.5	96.0	93.3	92.0	91.5	91.1
PVA(ST)	1.4	97.8	96.5	96.2	95.4	94.7
PVA(DT)	1.42	98.1	97.6	97.1	96.8	96.5

* The % change in the nitrogen content was calculated based on the original nitrogen percent in each sample (100%).

It is seen (table IV) that the % N decreases as the number of washing cycle decreases. This is observed regardless of the reactive polymer used. However, the decrement in the % N is lower with reactive polymer derived from low molecular weight dextrin or PVA. This indicate that reactive polymers with lower molecular weights are more intimately associated with the cotton structure and most probably such association involves chemical bonding and, therefore, more durability. It is as well to emphasize that reactive polymers based on PVA [i.e, PVA(ST), PVA(DT)] undergose smaller change in the % N with washing cycle as compared with the reactive hybrids. Meanwhile the lower molecular weight PVA(DT) is more resistance towards washing than reactive PVA(ST). This again reflects the effect of molecular weight of the reactive polymer on the mode of interaction of the latter with cotton cellulose. *It is further concluded that* reactive polymers based on PVA represent reactive finishes that are more durable, when applied to cotton fabric, than their mates based on dextrin.

CONCLUSION

Two reactive polymeric products were prepared. The first was N-methylol-carbamoylethyl poly(vinyl alcohol) (reactive PVA) synthesized via reaction of PVA with N-methylolacrylamide in alkaline medium. The second was methylolated polyacrylamide-dextrin hybrid, prepared through polymerization of dextrin with acrylamide followed by methylolation with formaldehyde. The two reactive polymers were reacted with cotton cellulose in the presence of acid catalyst (NH_4Cl) to achieve permanent size for cotton yarn and to impart easy-care properties to cotton fabric. Results obtained reveal,

a) that reactions of these reactive polymers with cotton cellulose are optimally carried out at 160°C using NH_4Cl (8 g/l) for 4 min,

b) that utilization of reactive PVA as a permanent size increases the tensile strength of cotton gauze provided that the % methylol of reactive PVA is kept at certain limit. Higher methylol decrease the tensile strength but with certainty that the size gauze exhibits much higher tensile strength than the unsized gauze,

c) that the elongation at break decreases after sizing and the decrement is higher the higher the % methylol, and,

d) that the fixation of the permanent size is better the lower molecular weight of the reactive PVA.

e) Similar results are found with the reactive hybrid when used as sizing agent.

f) On the other hand, utilization of the said reactive polymers as finishing agent enhances considerably the fabric performance assessed by tensile strength, wet and dry crease recovery angle, though, the wet recovery is significantly higher than the dry recovery. Better fabric performance is also achieved with lower than higher molecular weights reactive polymers.

g) It is further noted that reactive polymers derived from low molecular weight PVA is more durable than those derived from high molecular weight PVA. Meanwhile reactive polymers derived from PVA are more durable than that those from reactive hybrid.

References

[1] M. M. Hashem, A. Higazy and A. Hebeish, *Polymer and Polymer Composites,* **7,** 7, (1999).

[2] P. V. Seydel, "Textile Warp Sizing" *Phoenix printing, Inc. Atlanta,* GA (1981).

[3] R. E. Davidson and M. Sittig, *Water-soluble Resins,* Reinhold Publ. (1962).

[4] A.G. Grunan, *Belgian Patent,* 596.735 (1959).

[5] A. Moyse, to Hexagon Hous, Manchester, *Br. P.,* 849.368 (1960).

[6] E. F. Izard, to E. I. DuPond, *U.S.P.,* **2**, 169.250 (1939).

[7] B. H. Kress, to Quaker Chem., *U.S.P.,* **2**, 968.581 (1961).

[8] B. A. Kottes Anderws, J. G. Frick JR and J. David Reid, *Am. Dyestuff Reporter,* **58** (12), 15 (1970).

[9] N. A. Ibrahim, M. H. Abou-Shosha and M. A. Gaffer, *Colurage,* **45** (7) 13 (1998).

[10] M. Hashem, E. Bach, W. Kesting, A. Hebeish and E. Schollmeyer, *Die Angwandte Makromolecular Chemie,* **230,** 189 (1995).

[11] J. A. Radley "Examination and analysis of starch and starch products" *Applied Science Publishers LTD, London (1976).*

[12] Galliard T., "Starch; Properties and Potential" *John Wiley & Sons, New York, P. 110 (1987).*

[13] C. A. Finch, "Poly(vinyl alcohol)- Properties and Application" *John Wiely & Sons* (1974).

[14] A. Higazy, A. Bayazeed and A. Hebeish, *Starch/Stärke,* **39** (9) 319 (1987).

[15] A. I. Vogel, Elementary Practical Organic Chemistry Part 3: Quantitative Organic Analysis" *Longman, London* 2nd Ed., P 652 (1975).

[16] H. Petersen, *Milliand Inter., Textile Reports; English Ed.,* September, 756 (1985).

[17] ASTM Standard Test Method "Breaking Load and Elongation of Textile Fabrics", D-1682–94 (1994).

[18] ASTM Standard Test Method, D-1296–67 (1967).

[19] A. Hebeish, *J. Appl. Polymer Sci.,* **20,** 2631 (1976).