Reactive dyeing behaviour of ramie fabrics pretreated with different swelling agents and their rub fastness property

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Scoured and bleached ramie fabrics were pretreated separately with four swelling agents, viz. NaOH, EDTA, urea and phosphoric acid, and the consequent changes in tensile properties, extent of decrystallization, absorbency, dye uptake and fastness to washing light and rubbing for a monochlorotriazine reactive dye (C.I. Reactive Orange 13) were evaluated. Pretreatment with 20% urea or 20% NaOH under slack condition resulted in a more desirable balance in the above-mentioned properties including the improved dye uptake. Fastness to rubbing was poor and it was more pronounced at higher number of rub cycles. Both ring dyeing and higher coefficient of friction of ramie have been found to be responsible for this. To improve the rub fastness of reactive-dyed ramie fabric, post-treatment was carried out separately with catasoftener, silicone and polyethylene emulsion. Post-treatment with the last two finishing agents improved the rub fastness significantly on both NaOH (slack) and urea (slack) pretreated and reactive-dyed ramie fabrics.

Keywords: Dyeing, Polymeric finish, Ramie, Ring-dyeing, Rub fastness, Swelling pretreatment

1 Introduction
Recently, ramie has regained importance because of its increased share in the apparel and upholstery textiles in Asia and its sub-continents. Degummed ramie, in comparison with the relevant properties of cotton, is coarser, more heat-resistant, rapidly dryable, more durable, more lustrous, more rigid, less extensible with highly crystalline and highly oriented fine structure and has higher coefficient of friction, less moisture regain, higher tensile strength and improved wet strength. Highly crystalline and highly oriented fine structure of ramie makes the required dye diffusion difficult in comparison to that for cotton. In most of the cases, ring dyeing of ramie gives lower rub fastness. A few reports are available on the rub fastness study for pure cellulosics but little information is available on such study for ramie and that for reactive-dyed ramie pretreated with different swelling agents. Mercerization of ramie as pretreatment before dyeing has been investigated earlier by many workers. Recently, Cheek and Roussel have also made comparative studies on the dyeing of mercerized ramie, cotton and flax with low and high molecular weight direct dyes. But most of the azo direct dyes are now banned in European countries for their carcinogenic nature or possible harmfulness to human body. Therefore, reactive dyeing of ramie becomes much important in today's context. The present work was, therefore, undertaken to investigate the dyeing behaviour of ramie fabrics and their fastness properties when dyed with reactive dye with or without suitable pretreatments using different swelling agents and selective post-treatments subsequent to dyeing of pretreated ramie fabric.

2 Materials and Methods
2.1 Materials
2.1.1 Fabrics
Scoured and bleached plain-woven ramie fabric having the following specifications was used: weight, 130 g/m²; warp, 52.9 tex; weft, 25.6 tex; ends/dm, 190; and picks/dm, 230. For comparative purposes, plain weave cotton fabric having the following specifications was also used: weight, 109 g/m²; ends/dm, 315; picks/dm, 315; warp, 47 tex; and weft, 47 tex.

2.1.2 Dyes and Chemicals
A monochlorotriazine reactive dye (C.I Reactive Orange-13) obtained from a local dye supplier...
was used after necessary purification. Sodium chloride, sodium hydroxide, urea, phosphoric acid, EDTA (disodium salt of ethylenediamine tetraacetic acid), ammonium hydroxide, pyridine and acetic acid, all of AR grade, were used.

2.2 Methods

2.2.1 Pretreatment with Different Swelling Agents

The ramie fabric was pretreated by dipping in 20% (w/w) aqueous solution of urea or in 15% (w/w) aqueous solution of EDTA, keeping the material-to-liquor ratio (MLR) at 1:10, at room temperature (30 ± 2°C) for 30 min after which it was thoroughly washed with cold water and dried in air.

The phosphoric acid pretreatment of the ramie fabric was similarly done with 81% (w/w) aqueous phosphoric acid using same MLR and temperature for 30 min. The fabric was then washed thoroughly with water, neutralized with dilute ammonium hydroxide solution, rinsed, washed and dried in air.

Caustic pretreatment of the experimental cotton and ramie fabrics was carried out by dipping the fabric piece in 20% (w/w) aqueous NaOH for 30 min at room temperature (30 ± 2°C). The material-to-liquor ratio was kept at 1:10. The fabric was then washed with water, neutralized with 1.5% acetic acid solution, rinsed, washed and air dried. Mercerization of ramie fabric for extended time period (30 min) was also done using the same caustic liquor and same treatment condition but under tension by dipping the pretensioned ramie fabric held on the pin of a celluloid frame throughout the treatment period and the fabric was unloaded before air drying.

2.2.2 Dyeing with Reactive Dye

Dyeing of ramie and cotton fabrics with a reactive dye (CI Reactive Orange-13) was carried out using a material-to-liquor ratio of 1:50 and sodium chloride (70 g/l) and sodium carbonate (20 g/l) as additives to be added subsequently in the dyebath. The dyebath was initially set at 50°C with dye and the material was put in the dyebath. The temperature was gradually raised to 80°C and then sodium chloride was added in three instalments within 30 min, keeping the dyebath temperature at 80 ± 5°C. Finally, sodium carbonate was added in two instalments and dyeing was continued for further 45 min. After the dyeing was over, the material was rinsed cold, soaped with 5 g/l commercial grade detergent at 50°C for 15 min, washed in cold water and dried in air.

2.2.3 Post-treatment with Softener/Polymeric Emulsions

The dyed fabrics were padded in a two-bowl laboratory padder containing 5% (solid basis) polyethylene emulsion, adjusting the wet pick up at 80%. The fabrics were then touch dried at 80°C for 10 min and further subjected to a higher temperature (110°C) treatment for another 5 min in a laboratory hot air-drying and curing chamber.

For silicone emulsion treatment, the fabrics were similarly padded with 40 g/l silicone emulsion containing 4 g/l zinc acetate, adjusting the wet pick up at 80%. The fabrics were then touch dried at 80°C for 10 min and cured in a laboratory drying and curing chamber at 150°C for 4 min.

Catasoftener was applied by exhaustion process on the fabrics by dipping the fabric pieces in a solution containing 2.5% (solid basis) catasoftener at pH 4 (adjusted by acetic acid), keeping the material-to-liquor ratio at 1:20.

2.2.4 Physical and Chemical Testings

Absorbency of treated and untreated ramie fabrics was determined by measuring the iodine sorption value (ISV) following the procedure described by Marie10. X-ray crystallinity (%) of treated and untreated (control) ramie as well as cotton fibres was determined after separating the fibres from the respective fabrics to obtain the wide angle diffraction pattern with rotation powder method by nickel filtered CuKα radiation for 20 values between 10° and 30°, and the crystalline contents were evaluated using Segal's crystallinity index11. Weight losses were determined by usual oven dry weight basis.

Area shrinkage of the fabrics was determined following the usual method described elsewhere12.

The linear density (tex) of warp and weft yarns of the untreated (control) and treated ramie fabrics was determined after separating the warp and weft yarn from the corresponding fabric following the conventional procedure19 as given by ASTM D1059-87.

The coefficient of friction of treated and untreated (control) ramie fibres was measured following the conventional procedure14 using an inclined plane fibre friction testing instrument.

Breaking load and breaking elongation of untreated (control) and treated ramie fabrics were determined15 as per IS: 1969-1968 using Zwick-1445 CRT universal tensile testing machine.

The dye uptake of treated and untreated cotton and ramie fabrics, expressed as mg/g (dye in milligram per gram of fibre) was determined from the difference of initial dye concentration taken in the dyebath and the final dye concentration remaining
in the dyebath (including wash liquor) after exhaustion. The dye concentrations were estimated in the usual way \(^\text{16}\) by the absorbance spectrophotometry analysis using U-2000-Hitachi-UV-Vis absorbance spectrophotometer at the maximum absorbance wavelength of the respective dye solution using a calibration curve prepared for this purpose.

Fastness to washing of the reactive-dyed ramie fabrics was determined using a Launder-o-meter as per ISO-2 wash method \(^\text{16}\) and was assessed by grey scale as per ISO-105-A02 (loss of depth) and ISO-105-A03 (staining).

Colour fastness to rubbing was determined \(^\text{18}\) using SDL-electronic crockmeter as per IS: 766-1956 and the grey scale as per ISO-105-A02 and A03. Colour fastness to light was determined as per BS-1-6 : BOI-1978, using SDL-MBTF Lamp-microscallight fastness tester \(^\text{17}\).

K/S values computed by Kubelka-Munk equation \(^\text{16}\) were obtained by measuring the reflectance of the dyed and subsequently rubbed fabrics on Macbeth 2020 plus computer-aided reflectance spectrophotometer using the necessary softwares.

3 Results and Discussion

3.1 Effect of Pretreatment with Different Swelling Agents on Mechanical Properties and Fine Structure

3.1.1 Breaking Load and Extension

From Table 1, it is observed that phosphoric acid (PA) pretreatment lowers the breaking load to the highest extent (29.7%). The best effect is obtained in the case of NaOH (tension) pretreatment, where a measurable increase in breaking load is evident. In the case of EDTA and urea pretreatments, the loss of breaking load is only marginal. In all the pretreatments, breaking extension increases, except for NaOH (tension) pretreatment where the change is insignificant. Both the loss in breaking load and increase in breaking extension must be viewed as a consequence of the effect of decrystallization, partial loss of orientation and possible structural rearrangement set after swelling.

3.1.2 Frictional Behaviour

Table 1 shows that the frictional behaviour of the ramie fibre remains almost unchanged irrespective of the type of swelling pretreatments, keeping the surface behaviour almost same.

3.1.3 Area Shrinkage and Yarn Linear Density

The area shrinkage values of ramie fabrics pretreated with different swelling agents are given in Table 1. For each of the pretreatments, the area shrinkage value is higher than that for the control sample and it is maximum for PA pretreatment, showing maximum relaxation. The changes in the tex values of the warp and weft yarns of the pretreated ramie fabric are much in tune with the ultimate area shrinkage values obtained as a result of warp-way and weft-way yarn shrinkage in the fabric, except in the case of phosphoric acid pretreated sample, where the changes in the tex values of the yarns in both the directions are not commensurate with the extent of shrinkage. The lower extent of tex change, in spite of highest area shrinkage, in case of phosphoric acid treatment may be explained by some loss in mass from ramie in PA treatment due to hydrolysis, superseding the effect of reduction in the length of the yarn by shrinkage.

3.1.4 Decrystallization

In all the pretreatments to ramie fabric, phosphoric acid pretreatment results in maximum decrystallization, reducing the X-ray crystallinity from 63.3 to 39.2%. The extent of decrystalliza-

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Breaking load (N)</th>
<th>Breaking extension (°)</th>
<th>Coefficient of friction*</th>
<th>Area shrinkage (%)</th>
<th>Linear density of yarn, tex</th>
<th>Crystallinity%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated (Control)</td>
<td>568.00</td>
<td>9.15</td>
<td>0.63</td>
<td>1.2</td>
<td>53.0 26.0</td>
<td>63.3</td>
</tr>
<tr>
<td>20% NaOH (tension)</td>
<td>583.21</td>
<td>8.93</td>
<td>0.64</td>
<td>6.0</td>
<td>54.3 26.6</td>
<td>53.2</td>
</tr>
<tr>
<td>20% NaOH (slack)</td>
<td>570.34</td>
<td>11.27</td>
<td>0.64</td>
<td>8.0</td>
<td>54.6 27.0</td>
<td>52.3</td>
</tr>
<tr>
<td>15% EDTA (slack)</td>
<td>558.24</td>
<td>12.23</td>
<td>0.63</td>
<td>11.0</td>
<td>55.0 27.8</td>
<td>51.3</td>
</tr>
<tr>
<td>20% Urea (slack)</td>
<td>519.68</td>
<td>15.52</td>
<td>0.61</td>
<td>18.0</td>
<td>55.4 28.5</td>
<td>46.1</td>
</tr>
<tr>
<td>81% Phosphoric acid (slack)</td>
<td>399.04</td>
<td>19.43</td>
<td>0.62</td>
<td>24.0</td>
<td>56.0 29.0</td>
<td>39.2</td>
</tr>
</tbody>
</table>

*Coefficient of friction for control cotton, 0.24.

Crystallinity for control cotton, 63.0%.
tion for different swelling pretreatments is in the order: NaOH (tension) < NaOH (slack) < EDTA < urea < phosphoric acid (Table 1). Preferably, the small crystallites in the non-crystalline region are dissolved by the action of different swelling agents on ramie and thus non-crystalline region can be more accessible to external reagents or dyes for possible increase in intercrystalline free space in this region. In case of phosphoric acid pretreatment, the chances of some decrystallization even in crystalline region and some chain degradation can not be ruled out.

3.2 Effect of Pretreatment with Different Swelling Agents on Absorbency, Dyeability and Dye Fastness Properties

3.2.1 Absorbency

Absorbency data in terms of iodine sorption value (ISV) of differently pretreated ramie fabric (Table 2) follow the same trend as the extent of decrystallization after the same pretreatments, showing the highest iodine absorbency (more than four times of that for the control sample) for PA pretreated sample. Urea pretreatment shows considerable increase (more than three times of that for the control sample) in absorbency with only 8.6% loss in breaking load, about 70% increase in breaking extension and 27% decrystallization (Tables 1 and 2).

3.2.2 Dyeability

The reactive dye uptake (mg/g of fibre) for the control ramie fabric is much lower than that for the control cotton fabric. The ramie fabrics pretreated with different swelling agents show a noticeable increase in dye uptake when compared with that for the control ramie fabric. This may be due to creation of more accessibility of reactive dye sites by decrystallization and opening up of the compact structure of ramie by swelling agents.

NaOH pretreatments (both slack and tension) of ramie though show notable increase in reactive dye uptake, but the dye uptake level is lower than that for the control cotton fabric. 20% EDTA solution pretreatment shows reactive dye uptake more or less at the same level as for the control cotton.

20% urea solution pretreatment, without causing much sacrifice of mechanical properties, shows a reactive dye uptake level higher than that for the control cotton fabric, while 81% phosphoric acid pretreatment gives highest reactive dye uptake but with appreciable strength loss.

For the different swelling pretreatments studied, the observed trend of increase in reactive dye uptake (Table 2) is much in tune with the increase in iodine absorbency (Table 1) for the same pretreatments.

3.2.3 Dye Fastness Properties

3.2.3.1 Wash Fastness

Data presented in Table 2 show that the different pretreatments on ramie fabric have little or marginal effect on the fastness of reactive dyes to washing. Wash fastness for reactive dyes on ramie is fairly good like that on cotton, as expected due to the formation of covalent bond between reactive dye and ramie-cellulose.

| Table 2—Effect of pretreatment with different swelling agents on absorbency, dyeability (reactive dyes) and dye fastness properties of ramie fabric |
| Treatment | Absorbency (Iodine sorption value) mg/g | Dye uptake mg/g | Wash fastness | Rub fastness |
| | | | LD<sup>a</sup> | Staining<sup>b</sup> | 10 Cycles | 100 Cycles | Light fastness |
| | | | LD<sup>a</sup> | Staining<sup>b</sup> | LD<sup>a</sup> | Staining<sup>b</sup> | LD<sup>a</sup> | Staining<sup>b</sup> |
| Ramie Fabric | | | | | |
| Untreated (control) | 28 | 7.2 | 5 | 5 | 3 | 4-5 | 2 | 4-5 | 3-4 |
| 20% NaOH (tension) | 89 | 11.1 | 5 | 5 | 3-4 | 4-5 | 2-3 | 4-5 | 3-4 |
| 20% NaOH (slack) | 99 | 13.6 | 5 | 4-5 | 4 | 5 | 3 | 4-5 | 3-4 |
| 15% EDTA (slack) | 101 | 15.2 | 5 | 5 | 3-4 | 5 | 2-3 | 4.5 | 3-4 |
| 20% Urea (slack) | 121 | 19.2 | 5 | 5 | 4-5 | 5 | 3-4 | 4-5 | 3 |
| 81% Phosphoric acid (slack) | 132 | 21.3 | 5 | 5 | 4-5 | 5 | 3-4 | 4-5 | 2 |
| Cotton Fabric | | | | | |
| Untreated (control) | 34 | 15.2 | 5 | 5 | 5 | 4-5 | 5 | 4-5 | 3-4 |

<sup>a</sup>Loss of depth or change in colour was assessed as per ISO 105 A02 grey scale.

<sup>b</sup>Staining was assessed as per ISO 105 A03 grey scale.
3.2.3.2 Light Fastness

The light fastness of reactive dyes on both control ramie fabric and control cotton fabric is almost same, showing that there is little effect of the type of fibre. In the case of urea and phosphoric acid pretreated and subsequently reactive-dyed ramie samples, the light fastness ratings are 3 and 2 respectively (Table 2). This may be attributed to the increased absorbency or accessibility in the non-crystalline region after decrystallization by swelling agents, possibly facilitating the ease of diffusion of more moisture and oxygen for initiating the light fading mechanism.

3.2.3.3 Rub Fastness

Rub fastness ratings as assessed from the loss of depth of shade and from the extent of staining to the abrader cloth from ramie fabric are different, the former (loss of depth) being poorer in each case (Table 2), while the corresponding data in case of dyed control cotton fabric show the same rub fastness rating on assessment by both the methods. However, on pretreatments with different swelling agents, the poor rub fastness (assessed by loss of depth of shade) of ramie improves by more than one unit for phosphoric acid- and urea-pretreated and dyed ramie fabrics. This may be attributed to more diffusion and fixation of dyes to the core rather than surface after swelling pretreatments create easy dye diffusion facility and increased dye-accessible sites on decrystallization by the high swelling action of these two reagents. The other two swelling reagents, NaOH and EDTA, show little or marginal improvement in rub fastness (loss of depth) of ramie. However, when the NaOH pretreatment is carried out under slack condition, a small but measurable improvement in rub fastness (loss of depth) for reactive-dyed ramie is noticed (Table 2). Rub fastness ratings assessed from the extent of staining to the abrader cloth show almost no bearing on the type of pretreatments done.

On the extensive rubbing, i.e. for rubbing up to 100 cycles instead of 10 cycles, the rub fastness rating for reactive-dyed control ramie came down to 2 from 3 when assessed from the loss of depth of shade. But interestingly the rub fastness ratings assessed from the extent of staining to abrader cloth for 10 rub cycles and for 100 rub cycles do not show any significant difference.

Fig. 1 shows the K/S values of the reactive-dyed ramie and cotton fabrics as well as of the corresponding stained abrader clothes for different number of rub cycles. It is observed that the

![Fig. 1-K/S values of reactive-dyed ramie and cotton fabrics subjected to different number of rubbing cycles vis-a-vis corresponding abrader cloth. (1 & 5—without pyridine extraction; 2 & 6—with pyridine extraction; 3 & 7—abrader cloth for pyridine-extracted samples; and 4 & 8—abrader cloth for without pyridine-extracted samples)
extend this study for investigating the causes and remedies for this continual loss of depth of shade without staining to the abrader cloth, particularly on extensive rubbing.

3.3 Causes of Poor Rub Fastness (Loss of Depth) of Reactive-dyed Ramie on Extensive Rubbing

The observed poor rub fastness with continual loss of depth of shade without staining the abrader cloth on extensive rubbing (20-100 rub cycles) for reactive-dyed ramie fabric may be due to any one or possible combination of the followings:

(i) Relatively strongly held loose (unreacted) and hydrolyzed reactive dyes deposited on fabric surface may show poor rub fastness on higher rub cycles.

(ii) Higher coefficient of friction (0.63) of ramie (Table 1) with more irregular surface structure as compared to that of cotton (0.24) may produce higher abrasive force on the fabric surface during extensive rubbing and may cause breaking and ultimately loss of some dyed fibre mass.

(iii) The same as in (ii) may also happen without showing any loss of fibre mass, if the long-staple ramie fibres (on the fabric surface) are torn or broken on extensive rubbing, but still remain anchored, holding the broken fibres at the other end to the yarn structure in ramie fabric. The so-called free broken ends of the dyed ramie fibres with ring dyed cross-sections may be exposed to the dyed fabric surface and thereby may alter the reflectance of the rubbed portion, showing the apparent loss of depth without staining to the abrader cloth.

(iv) In consequence to ring dyeing (as observed in microscopic examination) for highly oriented and ordered structure of ramie fibre, the surface of the ring-dyed ramie fibre is when abraded for higher number of rub cycles, it may cause exposing of inner undyed layer progressively with the increase in rubbing cycles, which may lead to alteration of K/S value of the rubbed portion of the dyed ramie fabric accordingly.

To test if reason (i) has any bearing on the poor rub fastness, the pyridine-extracted reactive-dyed ramie and cotton fabrics were also subjected to extensive rubbing (from 0 to 100 rub cycles) and the corresponding changes in K/S values were measured after 10, 20, 30, 50 and 100 rub cycles. The results are presented in Fig. 1 (curves 2 & 6). It is observed from Fig. 1 that the loss of depth of shade, in terms of decrease in K/S value, on rubbing for 0 to 100 rub cycles, is very marginal for pyridine-extracted reactive-dyed cotton sample (curve 6) while that for corresponding reactive-dyed ramie fabric, continual loss of depth is significant (curve 2). However, it is also observed that the ultimate rate of decrease of K/S value, on rubbing for 0 to 100 rub cycles, for pyridine-extracted reactive-dyed ramie fabric (curve 2) is much lower than that found for the sample without pyridine extraction (curve 1). Also, the abrader cloths for pyridine-extracted samples of both ramie and cotton show no significant changes in K/S values on extensive rubbing (curves 3 and 7). These observations establish that the poor rub fastness of reactive-dyed ramie fabric is not governed at least by relatively strongly held loose (unreacted) or hydrolyzed reactive dyes deposited on ramie.

It is already mentioned in the last para of 3.2.3.3 that the loss of depth of shade of reactive-dyed ramie fabric continued without any measurable loss of dyed fibre mass and hence among the above-said possible reasons, the reason (ii) may be considered to be negligible but there is every chance that phenomenon explained in the reason (iii) may play a major role in this case. On microscopical examination, the presence of broken long-staple ramie fibre, anchored to the yarn assembly even after 100 cycles of rubbing, indicated that the reason (iii) is at least partly responsible for showing poor rub fastness (loss of depth) of reactive-dyed ramie on extensive rubbing.

Microscopical examination of the cross-sections of dyed control ramie showed ring dyeing effect, which may ultimately cause exposition of the inner undyed layer on higher abrasion on extensive rubbing and thus continual loss of depth of shade and consequent change in K/S value may be observed. Therefore, ring dyeing [reason (iv)] due to highly ordered and oriented fine structure of ramie is another factor responsible for such poor rub fastness (loss of depth) on extensive rubbing without staining to the abrader cloth.

Therefore, it may be concluded that the reasons (iii) and (iv) in mutual combination are responsible for the poor rub fastness of dyed ramie, particularly on extensive rubbing, showing continual loss of depth of shade without increasing stain to the abrader cloth.

The ring dyeing phenomenon can be reduced by swelling pretreatment allowing more dye diffusion, particularly when urea or phosphoric acid is used as swelling agent, as discussed in 1st para of section 3.2.3.3. Phosphoric acid pretreatment gives inferior mechanical properties of ramie and, therefore, 20% urea or 20% NaOH pretreatment (under slack condition) may be considered as a prospective pretreatment for ramie, which is even
better than NaOH pretreatment (under tension) or mercerization considering the overall balance of mechanical properties, dyeability and dye fastness (particularly rub fastness).

3.4 Effect of Selective Post-treatment with Different Softeners/Polymeric emulsions on Rub Fastness of Reactive-dyed Ramie

To mitigate or reduce the poor rub fastness (loss of depth of shade) problem of reactive-dyed ramie on extensive rubbing and consequent phenomenon explained in reason (iii) of section 3.3, attempts were made to suitably modify the surface characteristic of 20% NaOH (slack) pretreated and 20% urea pretreated ramie fabrics using selective softeners/polymeric emulsions such as catasoftener, silicone emulsion and polyethylene emulsion. Relevant rub fastness results (after these post-treatments) in terms of change in K/S values, are graphically presented in Fig. 2.

Catasoftener (cationic softener) post-treatment (curve 2) on NaOH-pretreated (slack) and dyed ramie, though deposited the fatty matters on the surface of the fibre to lubricate and soften the fibre surface it showed little improvement in rub fastness over slack-causticised ramie sample and at higher number of rub cycles, the improvement was very marginal as indicated by the corresponding curves 1 and 2. Catasoftener treatment on urea-pretreated ramie rather showed deterioration in rub fastness (corresponding curves 6 and 5), the reason for which is not understood from this study. Silicone finish suitable for producing a softer handle alongwith moderate film forming capacity showed a marked improvement in rub fastness (curves 3 and 7) in rub fastness for both NaOH (slack) and urea-pretreated ramie, even on extensive rubbing. From Fig. 2, it may also be observed that polyethylene emulsion, probably producing a smooth film over the fibre surface, showed only marginal loss of K/S value at the rubbed portion for both NaOH (slack) and urea-pretreated dyed ramie, retaining the physical appearance of the cloth almost intact even after 100 rub cycles (curves 4 and 8). This further supports the view [reason (iii) in section 3.3] that the surface frictional behaviour is one of the important factors responsible for poor rub fastness of reactive-dyed ramie fabric which can be reduced by post-treatment with silicone or polyethylene emulsion forming a soft and smooth surface film over the dyed ramie surface. Therefore, post-treatment, either with silicone or polyethylene emulsion, of reactive-dyed ramie fabric pretreated with either 20% NaOH or preferably with 20% urea, both in slack condition, can be considered to be a useful practical proposition if higher rub fastness is desired.

4 Conclusions

4.1 All the pretreatments, considered for the enhancement of accessibility, improve the reactive dye uptake of ramie fabric to different extents. Phosphoric acid though improves the accessibility to the highest extent but results in high loss (about 30%) of tensile strength. Pretreatment with 20% NaOH or 20% urea under slack condition shows appreciable amount of decrystallization [more than that obtained for NaOH (under tension) or mercerization process], considerable improvement in reactive dye uptake with low to moderate strength loss, indicating practical importance for possible industrial application.

4.2 Fastness to washing and light for reactive-dyed ramie are almost at par with those for similarly dyed cotton. However, the fastness to rubbing is generally poor for ramie, particularly at higher number of rub cycles, in comparison to that for cotton.

4.3 Highly oriented and ordered structure of ramie offers less dye accessibility (consequently less dye sites), resulting in (i) ring dyeing phenomenon and (ii) high coefficient of friction of the ramie fi-
bre, causing break of long-staple ramie fibre on extensive rubbing without detaching from fabric; these two reasons have been found to be the major responsible factors for lowering the rub fastness of reactive-dyed ramie.

4.4 Post-dyeing treatments with selective softeners or polymeric emulsions like silicone and polyethylene emulsion of suitably pretreated (particularly 20% NaOH or 20% urea pretreatment under slack condition at room temperature) ramie fabric improve the fastness to rubbing significantly for reactive-dyed ramie fabric and these pre- and post-treatments may be considered useful for practical application.

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