A study on dimensional parameters of 1×1 rib fabric produced on a flat bed double jersey knitting machine using ultrasonic technique

Sandip Mukherjee
Department of Fashion & Apparel, National Institute of Fashion Technology, Kolkata 700 098, India

Sadhan Chandra Ray
Department of Fabric Manufacture, Institute of Jute Technology, Kolkata 700 019, India

and

S K Punj
Department of Textile Technology, The Technological Institute of Textile & Sciences, Bhiwani 127 021, India

Received 5 October 2010; revised received and accepted 31 January 2011

An attempt has been made to investigate as well as to gain an insight on the non-dimensional parameters such as Uc, Uw, Us and Ur of the knitted fabrics produced on a double jersey flat bed machine using acrylic yarn. Fabric samples have been prepared by varying the stitch cam setting, take down load and yarn count in a 5.5 gauge flat bed knitting machine and then subjected to relaxation treatment by using conventional technique as well as mechanical energy of ultrasonic waves for maximum shrinkage. It is observed that this new relaxation technique produces similar dimensional and non-dimensional parameters of the fabric as obtained with the conventional relaxation treatments. The values of the four non-dimensional parameters such as Uc, Uw, Us and Ur follow a specific trend and these values are found to be comparable with the experimental values obtained by previous workers for fabrics knitted in circular knitting machine. Regression analyses have been made and regression equations are generated to study the effect of loop length on courses and wales (ribs) per cm at different stages of relaxation.

Keywords: 1×1 rib fabric, Dimensional parameters, Flat bed knitting machine, Loop length, Regression analyses, Ultrasonic waves

1 Introduction

In recent years, the knitting industry has witnessed a number of rewarding technological advances that have transformed knitting from an art, requiring the skill and experience of the knitter, to a more efficient industrial technique. The sciences of knitting have also been started to be developed for producing a finished knitted fabric of desired characteristics and dimensions. Many attempts have been made in recent years to rationalize the knitting process. In accordance to Munden the dimensions of the relaxed fabrics in the most simple weft knitted structure are solely determined by the length of the yarn in the knitted loop. Munden recognized two relaxed states, namely a dry relaxed state, taken up after some days exposure to air and a wet relaxed state, taken up after soaking in water. Nutting has shown that the wet relaxation process is irreversible, but the fabric dimensions depend upon water temperature used for relaxation and the regain of the fabrics when they are measured. The use of a single dry or wet relaxed state is not only convenient but a necessary simplification. Nutting and Leaf opined that, in a relaxed state, a relation between courses per unit length and loop length, for structures other than plain – knitted ones, would not be of the simple form. Smirfitt concentrated his attention on 1 × 1 rib structure and performed experimental work on wool fabrics. He concluded that these fabrics in a ‘tumble-relaxed’ state were described by ‘K’ factors analogous to those proposed by Munden for single jersey fabrics.

Smirfitt studied the fabrics in both these states and after being tumble dried. Smirfitt also investigated the effects of changes in loop length and yarn diameter on the physical properties of wet relaxed fabrics. The width-wise extension of 1×1 rib fabrics was also examined in details. Doyle described the phenomenon of high extensibility of 1×1 rib fabric which arises from the rotation of the links that join the

---

*To whom all the correspondence should be addressed. E-mail: sandip_m1995@rediffmail.com*
face and back loops. Nutting suggested that, this being so, initially most of the work done in extension will be again the torsional resistance of the yarn. A series of three non dimensional parameters was introduced by Knapton et al. to specify the dimensional properties of plain wool knitted structure. They opined that plain-knitted structures are rationally determinate structures only in the fully relaxed state, found after the fabrics have been thoroughly wetted out, briefly hydro-extracted and tumble dried. Knapton et al. also studied the dimensional properties of 1×1 rib and half-cardigan structures of knitted wool fabric and found similar behaviour like the plain structure. The effect of loop length on courses and ribs spacings was studied and several regression equations were derived at different stages of relaxation. Woolfardt and Knapton statistically analysed the results revealed from their studies on dimensional behavior of tumble-relaxed wool 1×1 rib structures and found that it is similar to plain knitted structure, i.e., course and wale units per unit length and width are related to loop length by simple expressions. Jeddi and Zarien introduced a series of non dimensional parameters \( U_c, U_w \) and \( U_s \) to specify the dimensional properties of the structure. They introduced the new technique of ultrasonic waves to obtain full relaxation of the circular bed knitted fabrics. By using this technique, it is observed that the U-values achieved in this method are higher than reported experimentally by previous workers. Therefore, they suggested that the ultrasonic waves technique is not only an advanced method in the relaxation process of cotton knitted fabric, but it requires less energy, water and detergents, and is more useful with a view to environmental protection than traditional relaxation methods. It is also reported that yarns with elastomeric components increase tightness factors which have a significant effect on dimensional behaviour, giving better dimensional stability to knitted fabrics. The study on the effect of resin finish on the dimensional stability of cotton knitted fabrics showed that resin finishing can effectively stabilize the change in dimensional stability. It was believed that the residual shrinkage in the fabric is closely related to the deformation of the yarn.

As the determination of loop length and dimensional parameters are of prime importance in defining the end use of the knitted fabrics, the present study is the continuation of the earlier studies in this field. So, the objectives of the present research work is to establish the dimensional constants of 1×1 rib knitted fabric, to investigate the relationship amongst the different knitted fabric parameters and to incorporate the principle of ultrasonic wave for obtaining fully relaxed fabric.

2 Materials and Methods

In order to study the dimensional properties of double jersey fabrics, fifteen 1×1 rib fabric samples were made on a flat bed double jersey knitting machine. Acrylic yarn was used to prepare the fabric samples. The fabric samples were subjected to dry relaxation, wet relaxation, washing and ultrasonic treatment for full relaxation. The fabric samples under different states of relaxation were analysed.

Following types of yarns were used to prepare the fabric samples (i) high bulk 2 ply acrylic yarn of count 73 tex, (ii) high bulk 3 ply acrylic yarn of count 158 tex and (iii) high bulk 4 ply acrylic yarn of count 146 tex.

2.1 Testing of Yarn Parameters

The yarn count was measured in the direct system (tex) under normal testing conditions. The essence of the method was that the five yarn leas of 100 m length in each case were prepared by a Wrap Reel (Motorised) [Make – M/s. Ramesh Machine Works; Type – R021A]. The yarn leas were weighed on an electronic balance [Make – Afcozet; Type – ER-120A]. From the above observations yarn linear density in terms of tex was calculated.

The tensile properties of the yarns were tested on an Instron universal tensile tester [Number – 4411 H2123; Model – 4411] using the gauge length 50 cm, crosshead speed 300 mm/min and full scale load range 0.5 kN. Total number of tests performed for each yarn sample was twenty five.

The breaking load, % strain and tenacity for each type of yarn were calculated. The yarn samples were tested to find unevenness, imperfections and hairiness on an Uster – UT-3 evenness tester using testing speed 100 m/min and time 3 min. The test results are shown in Table 1.

2.2 Preparation of Fabric Samples

The fabrics were knitted on the computerized power driven flat bed double jersey knitting machine [Make – M/s. Brothers Limited, Japan] using the gauge 5.5 and width 40 inch. Eighty needles were selected for preparing the yarn samples and fifteen samples were prepared on the flat bed machine.
Table 1—Yarn testing results

<table>
<thead>
<tr>
<th>Yarn Type</th>
<th>Count, tex</th>
<th>Breaking load, N</th>
<th>% Strain</th>
<th>Tenacity, cN/tex</th>
<th>U %</th>
<th>CV%</th>
<th>Hairiness index</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 ply</td>
<td>158</td>
<td>14.24</td>
<td>33.19</td>
<td>9.00</td>
<td>5.96</td>
<td>7.52</td>
<td>27.93</td>
</tr>
<tr>
<td>2 ply</td>
<td>73</td>
<td>6.22</td>
<td>38.55</td>
<td>8.50</td>
<td>8.09</td>
<td>10.19</td>
<td>27.20</td>
</tr>
<tr>
<td>4 ply</td>
<td>146</td>
<td>13.42</td>
<td>35.64</td>
<td>8.85</td>
<td>7.12</td>
<td>9.02</td>
<td>27.45</td>
</tr>
</tbody>
</table>

Table 2—Input parameters for knitting of fabric samples

<table>
<thead>
<tr>
<th>Fabric code</th>
<th>Yarn count, tex</th>
<th>Front bed cam setting, mm</th>
<th>Back bed cam setting, mm</th>
<th>Input tension g</th>
<th>Take down load g/wale</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>158</td>
<td>2.84</td>
<td>1.33</td>
<td>10</td>
<td>18.75</td>
</tr>
<tr>
<td>F2</td>
<td>158</td>
<td>3.52</td>
<td>2.06</td>
<td>10</td>
<td>18.75</td>
</tr>
<tr>
<td>F3</td>
<td>158</td>
<td>4.20</td>
<td>2.79</td>
<td>10</td>
<td>18.75</td>
</tr>
<tr>
<td>F4</td>
<td>158</td>
<td>3.52</td>
<td>2.06</td>
<td>10</td>
<td>6.25</td>
</tr>
<tr>
<td>F5</td>
<td>158</td>
<td>3.52</td>
<td>2.06</td>
<td>10</td>
<td>12.50</td>
</tr>
<tr>
<td>F6</td>
<td>158</td>
<td>2.84</td>
<td>2.06</td>
<td>10</td>
<td>18.75</td>
</tr>
<tr>
<td>F7</td>
<td>158</td>
<td>3.52</td>
<td>1.33</td>
<td>10</td>
<td>18.75</td>
</tr>
<tr>
<td>F8</td>
<td>158</td>
<td>3.52</td>
<td>2.79</td>
<td>10</td>
<td>18.75</td>
</tr>
<tr>
<td>F9</td>
<td>158</td>
<td>4.20</td>
<td>2.06</td>
<td>10</td>
<td>18.75</td>
</tr>
<tr>
<td>F10</td>
<td>73</td>
<td>2.84</td>
<td>1.33</td>
<td>10</td>
<td>18.75</td>
</tr>
<tr>
<td>F11</td>
<td>73</td>
<td>3.52</td>
<td>2.06</td>
<td>10</td>
<td>18.75</td>
</tr>
<tr>
<td>F12</td>
<td>73</td>
<td>4.20</td>
<td>2.79</td>
<td>10</td>
<td>18.75</td>
</tr>
<tr>
<td>F13</td>
<td>146</td>
<td>2.84</td>
<td>1.33</td>
<td>10</td>
<td>18.75</td>
</tr>
<tr>
<td>F14</td>
<td>146</td>
<td>3.52</td>
<td>2.06</td>
<td>10</td>
<td>18.75</td>
</tr>
<tr>
<td>F15</td>
<td>146</td>
<td>4.20</td>
<td>2.79</td>
<td>10</td>
<td>18.75</td>
</tr>
</tbody>
</table>

2.3 Total Combination of Input Parameters

Total fifteen combinations of input parameters were chosen by varying stitch cam setting, take-down load and yarn for producing fabric samples. The samples were prepared by incorporating three different take down loads. The stitch cam settings were altered at three levels for both the beds. Fabric samples (F1 – F15) were coded based on input parameters such as front bed stitch cam setting, back bed stitch cam setting, different take down loads and yarn count. The combinations of these parameters for all the fabric samples are shown in Table 2. In certain cases combinations were made by keeping the setting of one particular bed constant and varying the others.

2.4 Relaxation Treatments

Knitted fabrics are similar to woven fabrics in that they are subject to relaxation shrinkage. However, it has been found difficult experimentally to determine when a fabric has reached a totally relaxed state in which it is in a stable state with the minimum energy. The fabric samples were subjected to the following relaxation treatments:

(i) **Dry relaxation treatment**—This is the condition the fabric reaches after a sufficient period of time subsequent to being removed from the knitting machine. Fabric samples were placed on a flat surface at room conditions for 24 h.

(ii) **Wet relaxation treatment**—This is achieved by a static soak in water and flat drying of fabric. Fabric samples were immersed in water for 24 h followed by gentle rinsing and drying at room conditions on a flat surface for 24 h.

(iii) **Washing treatment**—This is achieved by soaking the fabric in water with agitation at around 60°C with 0.5 g/L of non ionic detergent for 30 min followed by gentle rinsing and then drying at room conditions for 24 h.

(iv) **Ultrasonic treatment**—Fabric samples were subjected to ultrasonic treatment for full relaxation. The specifications of the ultrasonic cleaner used and the conditions maintained for the present experiment are: brand–PCI, model–3.5 L100H, capacity–3 L, frequency – 33 kHz, water temperature– 50°C, and relaxation time period – 15 min.
Fabric samples were placed in the ultrasonic cleaning bath containing 3 L of water and 0.5g/L of non-ionic detergent was added in the bath before placing the fabric. Relaxation treatment was carried out for 15 min at 50°C. The fabric samples were then taken out, rinsed and dried at room conditions for 24 h. The relaxation treatment was repeated three times for every fabric sample. The first, second and third relaxation treatments are termed as Ultrasonic 1 (US-1), Ultrasonic 2 (US-2) and Ultrasonic 3 (US-3) states respectively.

2.5 Method of Fabric Analyses

In the present study, the dimensional parameters like courses per cm (c), wales or ribs per cm (w), loop length (L), length and width of the fabric samples were measured in the standard atmospheric conditions.

(i) Courses and wales (ribs) per cm—The numbers of courses and wales (ribs) per cm were counted randomly from ten different portions of the fabric samples for flat bed machine with the help of a needle and a measuring scale. From the observed ten readings the number of courses and wales per cm were calculated separately. This was performed at all different relaxation stages.

(ii) Stitch density —Stitch density was calculated from the product of courses and wales (ribs) per cm for all the samples at all different relaxation stages.

(iii) Loop length —Eighty needles were selected to prepare the samples. To measure the loop length the full course comprising 80 loops was unraveled from the fabric sample. One end of the yarn was fixed on a support by means of a cello tape and a load of 0.5 g/tex was applied at the other end to remove the crimp of the yarn or in other words to straighten the same. The length of the yarn was measured thereafter by means of a measuring tape. Twenty such observations were performed and the average value of the reading was calculated. The loop length was calculated using the following formula:

\[
\text{Loop length (L) = Uncrimped length of the yarn making 80 loops} \div 80
\]

3 Results and Discussion

3.1 Knitting Constants

It is established that courses per cm (c), wales per cm (w) and loop length (L) are related to each other by dimensionless constants (U-values). A series of four non-dimensional parameters, namely Uc, Uw, Us and Ur are used to specify the dimensional properties of double jersey knitted structures. Uc and Uw are dimensionless parameters called course constant and wale constant, whose values are fairly constant for each state of relaxation. Ur is the ratio Uc/Uw, a direct measure of the loop shape called the loop shape factor and Us is termed as stitch density constant which is the product of Uc and Uw.

In the present research work, the values of these dimensionless knitting constants (U - values) were obtained for 1×1 rib fabrics produced on flat bed knitting machine at different stages of relaxation treatments such as dry, wet, washing and ultrasonic and then subjected to statistical analyses for getting insight of the dimensional properties of the fabrics. The average numerical values of these parameters were calculated and compared with the values obtained by previous workers in this field.

The mean values of Uc, Uw, Us and Ur of 15 different fabric samples produced with different combination of input parameters at different stages of relaxation are shown in the Table 3. The mean U values in the fully relaxed state obtained in the present research work have been compared with the earlier findings as shown in the Table 4. It is found that the values obtained in the present research are very much similar to that of the study reported earlier. The range of average values of the constants for confidence interval at 95% level are also calculated and it is observed that almost all the values are within the range suggesting that the U - values for different fabrics irrespective of relaxation stages are constant, supporting the work of previous researchers. It is observed that the Uc and Us values gradually increase from dry relaxed condition to wet relaxed condition to tumble drying and ultimately to fully relaxed state where it is subjected to three consecutive ultrasonic treatment. This signifies that the shrinkage of the fabric is higher when it is subjected to ultrasonic treatment as compared to normal washing.

It is observed that the value of Uc gradually increases from 9.52 in the dry relaxed condition to 9.87 in wet relaxed condition to 10.27 after tumble drying and ultimately to 10.40 at fully relaxed state where it is subjected to three consecutive ultrasonic treatments. This signifies that on subsequent relaxation process the fabric undergoes progressive length-wise shrinkage, resulting in gradual decrease in the course spacing. It is established that the loop length remains almost constant irrespective of the relaxation treatments, thus the value of
Table 3 — Mean values of the dimensional constants of knitted fabric samples at different stages of relaxation

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Uc</td>
<td>9.52</td>
<td>10.60</td>
<td>10.27</td>
<td>10.24</td>
<td>10.42</td>
<td>10.40</td>
</tr>
<tr>
<td>Uw</td>
<td>6.82</td>
<td>7.20</td>
<td>6.85</td>
<td>6.86</td>
<td>6.73</td>
<td>6.67</td>
</tr>
<tr>
<td>Us</td>
<td>64.79</td>
<td>71.03</td>
<td>70.28</td>
<td>70.15</td>
<td>70.05</td>
<td>69.40</td>
</tr>
<tr>
<td>Ur</td>
<td>1.41</td>
<td>1.38</td>
<td>1.51</td>
<td>1.50</td>
<td>1.56</td>
<td>1.57</td>
</tr>
</tbody>
</table>

Uc gradually increases with subsequent stages of relaxation. The variation in Uw values is not very significant when the fabrics are subjected to different relaxation stages. It is also observed that the value of Us changes from 64.79 in the dry relaxed condition to 71.03 in wet relaxed condition to 70.28 after tumble drying and ultimately to 69.40 at fully relaxed state due to three consecutive ultrasonic treatments. It is observed that the value of Ur initially slightly decreases from 1.41 in the dry relaxed condition to 1.38 in wet relaxed condition. Thereafter, it increases to 1.51 after tumble drying and ultimately to 1.57 at fully relaxed state due to three consecutive ultrasonic treatments. The change in the Ur value suggests that there is a significant effect on the shape of the loop which changes as the fabrics are subjected to various relaxation treatments. Due to the ultrasonic treatment the increase in shrinkage of the fabric is owing to the fact that the energy in fabric reaches its lowest degree. It can be said that the use of vibrations of the ultrasonic waves obviously results in permitting more inter-yarn and inter-fibre slippage and thus facilitates the attainment of minimum energy state. It removes the internal forces exerted during knitting operations and decreases the potential energy of the fabrics. Therefore, this treatment is not only a new and advanced technique in the relaxation process of knitted fabric, but it requires less energy, time, water and detergents and is more useful with a view to environmental protection as compared with traditional relaxation methods.

The U-values of the knitted fabric samples six different stages of relaxation treatments were subjected to ANOVA analyses (Table 5). From the analyses p-values and F-critical values are obtained. The p-values in case of Uc and Ur are less than 0.05, indicating that there are significant differences at different stages of relaxation. The p-value is the probability level at which the null hypothesis, means equality of averages, just rejected. If the p-value is less than 0.05 there is sufficient scope of difference of the average values, therefore the significant difference exists among the average or the mean values at 5% level or it is accepted at 95% confidence limit. To identify the significant differences, the least significant difference (lsd) or critical difference (cd) value at 5% level of significance was also calculated.

3.2 Effect of Loop Length on Courses and Wales (Ribs) per Centimeter

In order to find the best regression between courses per cm (c) and loop length (L) at different stages of relaxation, the values of 1/courses per cm is plotted against loop length using standard statistical software (MS-Excel). The regression equations between courses per cm (c) and loop length (L) at different stages of relaxation are shown in Table 6. The relationships between c and 1/L as well as between 1/c and L or the numerical regression equations with and without intercept at different stages of relaxation are obtained and shown in Table 6. In accordance to Woolfardt and Knapton the regression analyses between courses per cm (c) and loop length (L) at different stages of relaxation are shown in Table 6. The relationships between c and 1/L as well as between 1/c and L or the numerical regression equations with and without intercept at different stages of relaxation are obtained and shown in Table 6. In accordance to Woolfardt and Knapton the regression analyses between courses per cm (c) and loop length (L) at different stages of relaxation are shown in Table 6. The observed (O) and expected (E) values of 1/c against the loop length at four different stages of relaxation i.e. dry, wet, wash and ultrasonic, are plotted and the nature of the curves is shown in Fig. 1 for dry and ultrasonic state. The observed
Table 5—ANOVA (single factor analyses) for dimensional constants values at different stages of relaxation

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
<th>F critical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>9.445147</td>
<td>5</td>
<td>1.889029</td>
<td>6.844127</td>
<td>2.12E-05</td>
<td>2.323126</td>
</tr>
<tr>
<td>Within groups</td>
<td>23.18462</td>
<td>84</td>
<td>0.276007</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>32.62977</td>
<td>89</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uw Value</td>
<td>2.584698</td>
<td>5</td>
<td>0.51694</td>
<td>1.289033</td>
<td>0.276376</td>
<td>2.323126</td>
</tr>
<tr>
<td>Between groups</td>
<td>33.68643</td>
<td>84</td>
<td>0.401029</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within groups</td>
<td>36.27113</td>
<td>89</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Us Value</td>
<td>384.2072</td>
<td>5</td>
<td>76.84143</td>
<td>1.908109</td>
<td>0.10152</td>
<td>2.323126</td>
</tr>
<tr>
<td>Between groups</td>
<td>3382.763</td>
<td>84</td>
<td>40.27099</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within groups</td>
<td>3766.97</td>
<td>89</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ur Value</td>
<td>0.472788</td>
<td>5</td>
<td>0.094558</td>
<td>4.027297</td>
<td>0.002522</td>
<td>2.323126</td>
</tr>
<tr>
<td>Between groups</td>
<td>1.972249</td>
<td>84</td>
<td>0.023479</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within groups</td>
<td>2.445036</td>
<td>89</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6—Regression equations between courses per cm (c) and loop length (L) at different stages of relaxation

<table>
<thead>
<tr>
<th>Relaxation stages</th>
<th>c and 1/L With intercept</th>
<th>Without intercept</th>
<th>1/c and L With intercept</th>
<th>Without intercept</th>
</tr>
</thead>
<tbody>
<tr>
<td>DR</td>
<td>c = -0.509+107.48/L</td>
<td>c = 95.410/L</td>
<td>1/c = -0.039 + 0.012*L</td>
<td>1/c = 0.0105*L</td>
</tr>
<tr>
<td>WR</td>
<td>c = -0.314+106.240/L</td>
<td>c = 98.784/L</td>
<td>1/c = -0.027+0.113*L</td>
<td>1/c = 0.0101*L</td>
</tr>
<tr>
<td>WASH</td>
<td>c = 0.7068+119.718/L</td>
<td>c = 102.934/L</td>
<td>1/c = -0.047+0.117*L</td>
<td>1/c = 0.0097*L</td>
</tr>
<tr>
<td>US</td>
<td>c = 0.4018+94.448/L</td>
<td>c = 103.900/L</td>
<td>1/c = 0.005+0.009*L</td>
<td>1/c = 0.0096*L</td>
</tr>
</tbody>
</table>

Fig. 1—Trends showing observed and expected values of 1/c of fabric samples in dry, relaxed and ultrasonic state.
Table 7—Regression equations between wales per cm (w) and loop length (L) at different stages of relaxation

<table>
<thead>
<tr>
<th>Relaxation stages</th>
<th>w and 1/L</th>
<th>1/w and L</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With intercept</td>
<td>Without intercept</td>
</tr>
<tr>
<td>DR</td>
<td>$w = 2.1172 + 17.2999/L$</td>
<td>$w = 67.431/L$</td>
</tr>
<tr>
<td>WR</td>
<td>$w = 1.6962 + 31.1619/L$</td>
<td>$w = 71.4336/L$</td>
</tr>
<tr>
<td>WASH</td>
<td>$w = 1.5451 + 31.2974/L$</td>
<td>$w = 67.9836/L$</td>
</tr>
<tr>
<td>US</td>
<td>$w = 1.5528 + 29.5100/L$</td>
<td>$w = 66.0348/L$</td>
</tr>
</tbody>
</table>

Fig. 2—Trends showing observed and expected values of 1/w of fabric samples in dry, relaxed and ultrasonic state

plotting 1/c against L with similar values of correlation coefficient R ranging from 0.998 - 0.999, R² ranging from 0.996 - 0.998 and adjusted R² ranging from 0.924 - 0.927, have a very small value of standard error of 0.011 - 0.013 which is much less than the previous relations.

Similarly in order to find the best regression between wales per cm (w) and loop length (L) at different stages of relaxation, the values of 1/wales per cm is plotted against loop length using standard statistical software (MS-Excel). The regression equations between wales per cm (w) and loop length (L) at different stages of relaxation are shown in the Table 7. The relation between w and 1/L as well as between 1/w and L or the numerical regression equations with and without intercept at different stages of relaxation are obtained and shown in the table. In accordance to Woolfardt and Knapton⁴, the regression analyses between wales per cm and 1/loop length was also explored. Although this relation is very much similar with the relation given by Knapton in his research findings but in the present case the relation between 1/w and L is more significant due to low value of standard error obtained as compared to the relation between w and 1/L.

The observed (O) and expected (E) values of 1/w against the loop length at four different stages of relaxation (dry, wet, wash and ultrasonic) are plotted and the nature of the curves are shown in Fig. 2 for dry and ultrasonic state. The trend is similar for wet relaxation and washing state. From the above figures it is clearly visible that both the curves are very near to each other which justifies that the relationship between 1/w and L under different stages of relaxation has been derived very accurately and hence the derived relationship can predict the desired value which is not covered under the experiment.

The regression analyses for the relationship between w and 1/L as well as 1/w and L at different stages of relaxations are made and the values of correlation coefficient R, R² and adjusted R² with significant intercepts are obtained. For significance test the p-values are also calculated. In all the cases it is observed from the value of correlation coefficient R, R² and adjusted R² that the relationship is highly significant by plotting w against 1/L. But in the present research work, the most significant regression equations obtained at different stages of relaxation by plotting 1/w against L with similar values of correlation coefficient R ranging from 0.995 to 0.998, R² ranging from 0.990 to 0.996 and adjusted R² ranging from 0.918 to 0.924, have a very small value of standard error of 0.022 to 0.037 which is much less than the previous relations.

4 Conclusion

The values of dimensionless knitting constants such as course constant (Uc), wale constant (Uw), stitch density constant (Us) and loop shape factor (Ur), obtained in 15 fabric samples made on flat bed double jersey machines by varying different input
parameters, do not show much variations and there is no significant difference between the values at 95% confidence limit. These values obtained in the study are also in line with the findings of the previous works in this field. The values of Uc, Us and Ur increase progressively from dry relaxed state to wet relaxed state and washing and ultimately reach to a stable maximum value at fully relaxed state due to three consecutive ultrasonic treatments. This signifies that on subsequent relaxation process the fabric undergoes progressive length-wise shrinkage, resulting in gradual decrease in the course spacing. It is also observed that the loop length remains almost constant irrespective of the relaxation treatments as already reported in the literature. Thus, from the experimental results it can be concluded that among the relaxation treatments the ultrasonic wave treatment is a suitable and advanced technique for better dimensional stability of 1×1 rib knitted acrylic fabric. The effect of loop length (L) on courses and wales (ribs) per cm at different stages of relaxation has also been studied. The best fitted linear regression equations between 1/c or 1/w and L have been derived in the case of flat knitted fabrics. The results of these equations have very small standard error as compared to the regression equations derived in earlier studies between c or w and 1/L. The intercepts of the regression equations in the dry relaxed state are visible and are of negative sign and their magnitudes are considerably larger, which has a decreasing trend in the subsequent stages of relaxation treatments and the values are least when the fabric samples are subjected to ultrasonic treatments. It can only be explained that the intercepts are the results of changes in processing variables during knitting such as take down load, knitting tensions and yarn frictional characteristics governing the magnitude and sign of the intercepts and not due to the effects of yarn diameter.

References