1. Introduction

Knittability and yarn damage evaluation in the knitting process receive increasingly more attention, which plays an important role in improving the quality of knitted articles, machine modifications, and even in the development of high-performance technical textiles. Researchers employed different methods to investigate yarn damage during knitting and evaluated the properties of knitted fabrics using different structures and machine settings [1–4]. Bhatt investigated that during loop formation, the yarn is subjected to tensile, bending, and torsional deformation. Bhatt also stated that the tensile, bending, and torsional rigidities of yarn are responsible for causing resistance to the deformation of yarn into a loop, and those properties also affect the magnitude and position of peak tension inside the knitting zone [5].

The effect of diverse integrated mechanism and knitting parameters on tensile strength failure of the reinforced unraveled yarns has been found in a good agreement of yarn damage and mechanical losses in a knitting process [6]. A quantitative approach has been developed to examine the degree of glass filaments’ breakage after the knitting process by unraveling the yarn from the knitted fabrics with the optimization of yarn tension, cam-setting, and some other machine parameters. The microscopic observations clearly indicate the yarn damage during the knitting process with the ultimate result that the tensile, bending, and frictional properties of the yarns play a vital role to determine the knittability of the yarns [7].

The installation of conductive yarns in fabrication (weaving, knitting, or embroidery) is getting more attention in the fashion industry and daily life usage products. In this scenario, the smart textiles worn by the people are under dynamic stresses. The study confirms the damaging effects on the silver-coated nylon yarns in stitching or soutache embroidery. The mechanical behavior of bending, tensile, and shear stresses causes deterioration of yarns, which become worst with increasing mechanical forces and eventually result in the loss of electrical conductivity [8]. For textile materials, cut behavior can be proven to be a complicated process to study because a textile fabric is an array of fiber bundles or yarns, put together in such a way that the final product has stability and is locked together to give a one-piece structure [9].
During the knitting process, the proportion of fiber damage for basalt filament yarn is lower than that of glass fiber yarn as it has a higher value of the frictional coefficient. He further suggests that for suitable cam-setting, the yarn damage can be minimized for both basalt and glass filament yarns. For the similar cam setting, with the higher value of the frictional coefficient, the yarn has lower loop length, whereas the 1 x 1 rib produced with higher yarn frictional coefficient has longer loop length [10]. The effect of knitting action on the yarn surface results in protruding fibers from the yarn surface because the shearing force of the knitting needles acts along the yarn’s cross-section. The coarser yarns remain attached to the yarn surface, but the fibers from finer yarn come out of the surface and result in transitory twisting change along the yarn, and the fibers are sheared off from the yarn structure [11]. Many factors affect the yarn friction. Yarn stretching force is one of the leading factors, which influences all dynamic frictional features. The friction is also related to bending angle, yarn delivery speed, yarn surface properties, and so on. [12-16].

The literature review indicates that the factors influencing the yarn damages and knittability are complex. This article conducted a comprehensive evaluation of yarn damages before knitting and after being unraveled from plain, and 1 x 1 rib fabric knitted on the computerized flat knitting machine. The mechanical properties of yarn including tensile, bending, shearing, and surface frictional properties were tested, and the microscopic analysis of unraveled yarns from plain and 1 x 1 rib fabric, as compared to the original yarns, has also been carried out. For yarn’s cross-sectional shearing properties testing, this article self-designed an innovative “Yarn Shear Testing Device,” which proved to be feasible and workable. The methodology and results could guide knitters to effectively improve the quality of knitted products, scientific evaluation of knittability of yarns, and even in the development of high-performance technical textiles.

2. Experimental

2.1. Raw materials, knitted structures, and machines

In this study, five different commercially available and commonly used yarns including cotton, acrylic, viscose, polyester, and wool are selected as raw materials, which are plied with the same count of 18/2 tex, then knitted into plain and 1 x 1 rib structures on the computerized Gauge 12 flat knitting machine with the model of Long Xing (LXC-252SCV) from China. Yarn and fabric specifications are given in Table 1.

| Materials  | Yarn fineness (tex) | Fabric density |
|-----------|---------------------|---------------|
|           | wpi*cpi             | wpi*cpi       |
|           | (plain)             | (1x1 rib)     |
| Cotton    | 18/2                | 24*20         |
|           |                     | 34*24         |
| Wool      | 18/2                | 24*17         |
|           |                     | 30*22         |
| Acrylic   | 18/2                | 25*17         |
|           |                     | 34*24         |
| Polyester | 18/2                | 25*20         |
|           |                     | 32*24         |
| Viscose   | 18/2                | 28*28         |
|           |                     | 28*26         |

Note: ‘wpi’ is the number of wales per inch and ‘cpi’ is the number of courses per inch.

Figure 1. Yarn bending testing
of yarn and then moves upward to stretch, and the yarn gets sheared across the cutting edge.

2.2.4. Yarn surface properties testing

Two different methods have been adopted to evaluate changes in surface properties before and after being unraveled. These are the Kawabata FB-4 surface testing method and slope board methods, respectively.

KES FB-4 surface tester has been used to measure the surface roughness (SMD) and dynamic frictional coefficient (MIU) of the yarn samples in such a way that the yarns are closely arranged in a parallel way with an equal distribution of 14 yarns/cm on a 20 x 20 cm paper in the range of 12 cm by leaving 4 x 4 cm from both sides of the paper (as shown in Figure 3).

The slope board method is conducted to measure the yarn’s static frictional coefficient. Yarns arranged in parallel on the glass-covered slope board. A 99.47 g slider block is prepared to slide over the attached yarns on the glass. Parallel arranged yarns are aligned under the slider surface, as demonstrated in Figure 4. The angle (θ) of slope board inclination can be adjusted. The angle θ is marked when the slider starts to move.

The static frictional coefficient can be calculated by equation $\mu = \tan\theta$.

2.2.5. Microscopic analysis of the yarns

To analyze the effect of knitting actions on the yarn surface, an optical microscope with the magnification of 500 times has been used with the model (Panasonic WV-CP504DCH). Moreover, the effect of the knitting actions on the surface morphology of the yarns is also compared before knitting and after being unraveled from the knitted fabrics.

3. Results and discussions

3.1 Tensile properties change

The stress-strain curves for the original yarns and the unraveled yarns from different knitted structures (i.e., plain and 1 x 1 rib) are plotted in Figure 5, whereas Figure 6 shows the tested yarn tensile modulus, which indicates that values of tensile modulus decrease obviously for all unraveled yarns in such a way, that is, the modulus of the yarn unraveled from 1 x 1 rib fabrics is lower than that of unraveled yarn from plain fabrics. However, the tensile strength of the unraveled yarns from 1 x 1 rib knit is lower than those of unraveled yarns from plain-knitted fabrics. In addition, the elongation of all unraveled yarns increases, but the elongation of unraveled yarn from 1 x 1 rib is higher than that of the plain. The reason behind this fact is the geometrical deformation in the yarn caused by the knitting actions/structures. Moreover, it confirms that the degree of geometrical deformation in the result of knitting process varies with respect to knitting structures, which affects the rate of loss of tensile modulus; which confirms the findings of Tian Hui’s study [17], that is, reknitting after deknitting can increase the elongation of the fabric because of the much-crimped state that leads to bigger geometrical deformation, but the tensile strength reduces. Figure 5 shows that as compared to the original yarn, the maximum decrease in elastic modulus is 4.67% for unraveled yarns from plain-knitted fabrics and 9.12% for unraveled yarns from 1 x 1 rib-knitted fabrics, which also
suggests that the knitting actions affect the different yarn types to different degrees. The statistical test ($t$-test for means) in Table 2 points toward that the significantly changed values in the tensile loss have been observed for all the yarns after knitting actions (plain knit and rib 1 x 1). The maximum significant values of tensile properties were observed for the cotton unraveled yarns for both the knits (i.e., plain and rib 1 x 1). However, the least significant results of the tensile values were observed for polyester unraveled yarns. It confirms that knitting is a dynamic process, and both the knitting actions significantly influenced the tensile properties of all different types of yarns opted in the experiment.

3.2. Bending properties change

Figure 7 shows the curves of bending moment against curvature for all the tested yarns. The values of bending modulus are given in Figure 8, which shows the loss in the bending modulus of the yarns unraveled from plain and 1 x 1 rib-knitted fabrics; however, the bending modulus of yarns unraveled from plain fabrics is higher than that of unraveled from 1 x 1 rib knit. The results can be attributed to the geometrical deformation in the unraveled yarns, which is related to the loop characteristics, such as loop length, loop shape, and the elastic properties of the yarn. The original yarn, which does not undergo the action of any external damaging forces, and the cohesive forces

![Figure 4. Static Frictional coefficient testing by Slope Board method](image)

![Figure 5. (a) Typical stress-strain curves for original yarns (b) stress-strain curves for yarns unraveled from plain knitted fabrics (c) stress-strain curves for yarns unraveled from 1x1 rib knitted fabrics.](image)
is 28.99% for unraveled yarns from plain-knitted fabrics and 30.44% for unraveled yarns from rib-knitted fabrics, which indicates that the yarn damage impact on bending properties is related to different knitting actions. Table 3 shows the effect of different knitting actions on yarn bending properties. The statistical test (t-test for means) in Table 3 confirms that the knitting action has a significant effect on different yarns. Significant changes in the bending values have been observed for all the yarns before and after knitting actions (plain knit and rib 1 x 1). Highly significant results of bending properties were observed for the polyester unraveled yarns for both the knits (i.e., plain and rib 1 x 1). However, the least significant results of the bending values were observed for acrylic unraveled yarns. It confirms that both the knitting structures/actions have a significant effect on bending properties of different yarns selected for the experiment.

### Table 2. Statistical analysis for tensile property

| Material | YBK N | Mean | Std. Deviation | Std. Error Mean | p-value |
|----------|------|------|----------------|-----------------|---------|
| Cotton   | YBK 10 | 2.5718 | 0.04055 | 0.01282 | 1.00E-06 |
|          | UPF 10 | 2.4536 | 0.03333 | 0.01054 | 1.55E-07 |
|          | URF 10 | 2.4421 | 0.03055 | 0.00966 | 0.001 |
| wool     | YBK 10 | 2.9610 | 0.05657 | 0.01789 | 6.75E-07 |
|          | UPF 10 | 2.8450 | 0.04243 | 0.01342 | 0.001 |
|          | URF 10 | 2.6972 | 0.04422 | 0.01398 | 6.75E-07 |
| Polyester| YBK 10 | 4.3351 | 0.21055 | 0.06538 | 3.70E-05 |
|          | UPF 10 | 4.2810 | 0.04761 | 0.01506 | 0.32 |
|          | URF 10 | 4.2036 | 0.03432 | 0.01085 | 6.40E-05 |
| Acrylic  | YBK 10 | 3.7248 | 0.05533 | 0.01751 | 3.20E-07 |
|          | UPF 10 | 3.6170 | 0.04690 | 0.01483 | 0.032 |
|          | URF 10 | 3.3196 | 0.06412 | 0.02028 | 4.60E-05 |
| Viscose  | YBK 10 | 3.4639 | 0.06018 | 0.01903 | 6.40E-05 |
|          | UPF 10 | 3.3196 | 0.05926 | 0.01874 | 6.40E-05 |
|          | URF 10 | 3.2675 | 0.06412 | 0.02028 | 4.60E-05 |

YBK = Yarn before knitting, UPF = Unraveled yarn from plain knitted fabric, URF = Unraveled yarn from 1+1 rib knitted fabric. Level of significance at (P < 0.05)

![Figure 6. Yarn tensile moduli before knitting and after being unraveled among the fibers play an important role in the behavior of yarn to act just like a straight rod and, therefore, give higher values of bending modulus. After being subjected to external forces during knitting (in the case of yarns unraveled from plain and 1 x 1 rib), the cohesive forces among the fibers decrease, resulting in a decline in the bending modulus. The cross-section of yarn unraveled from 1 x 1 rib becomes flattened, and the cohesive forces among the fibers are reduced that facilitate the yarn’s bending. It can be found from the results in Figure 8 that the maximum loss in bending modulus is 28.99% for unraveled yarns from plain-knitted fabrics and 30.44% for unraveled yarns from rib-knitted fabrics, which indicates that the yarn damage impact on bending properties is related to different knitting actions. Table 3 shows the effect of different knitting actions on yarn bending properties. The statistical test (t-test for means) in Table 3 confirms that the knitting action has a significant effect on different yarns. Significant changes in the bending values have been observed for all the yarns before and after knitting actions (plain knit and rib 1 x 1). Highly significant results of bending properties were observed for the polyester unraveled yarns for both the knits (i.e., plain and rib 1 x 1). However, the least significant results of the bending values were observed for acrylic unraveled yarns. It confirms that both the knitting structures/actions have a significant effect on bending properties of different yarns selected for the experiment.

### 3.3. Shearing properties change

To assess the yarn damage in terms of shearing modulus, the shear stress-strain curves are drawn in Figure 9 for all the yarns under consideration, which shows the remarkable decrease of shear modulus for unraveled yarns. Figure 10 shows that the shearing modulus values sharply decrease for the unraveled yarns in such an order that the values of shearing modulus of the unraveled yarns from 1 x 1 rib are lower than those of the yarns unraveled from plain. The yarn’s geometrical deformation (in terms of loop characteristics, i.e., loop shape, loop length, and elastic properties of yarns) due to knitting actions in the unraveled yarns increases the impact of the shear forces, and the highest impact is recorded for the yarns unraveled from
1 x 1 rib-knitted fabrics. It is observed from Table 4, that knitted actions (plain knit and rib 1 x 1) significantly ($p < 0.05$) affect the yarns in terms of shearing properties loss for different yarn types.

The ultimate contraction in shear modulus is 60.66% for unraveled yarn from plain-knitted fabrics and 81.01% for unraveled yarn from rib-knitted fabrics, which implies that the yarn damage in terms of loss in shearing properties is very sensitive to different materials and different knitted structures.

### 3.4. Surface properties change

Figures 11 and 12 confirm that the values of static frictional coefficient and dynamic frictional coefficient of yarns unraveled from 1 x 1 rib-knitted fabrics are greater than those of the values of yarns unraveled from plain-knitted fabrics. The results correlate with the findings of Fouda et. al. [18] that the frictional coefficient for 1 x 1 rib knit was higher than that of the plain knits because the tension increased for 1 x 1 rib knit as compared to the plain knit. Furthermore, the frictional area between the yarn and the needle hook during the loop formation also increased. Static frictional values are higher than the dynamic frictional values as indicated in Figures 11 and 12.

Figure 11 reveals that the highest increase in the static frictional coefficient is 10.54% for the unraveled yarn from plain and 23.97% for yarn unraveled from 1 x 1 rib-knitted fabrics. Figure 12 indicates the utmost increase in the dynamic frictional value (MU) is 6.99% for unraveled yarn from plain and 24.72% for yarn unraveled from 1 x 1 rib-knitted fabrics, which suggests that the yarn surface damage in different knitting actions is perceptible for different types of yarn. Tables 5 and 6 illustrate...
### Table 3. Statistical analysis for bending property of yarns

| Material | N  | Mean  | Std. Deviation | Std. Error Mean | p-value |
|----------|----|-------|----------------|-----------------|---------|
| Cotton   | 4  | 0.00048 | 0.000009     | 0.000005       |         |
|          | 4  | 0.00040 | 0.000009     | 0.000005       | 0.001   |
|          | 4  | 0.00038 | 0.000005     | 0.000003       | 2.09E-05|
| wool     | 4  | 0.00157 | 0.000011     | 0.000006       |         |
|          | 4  | 0.00140 | 0.000013     | 0.000007       | 1.36E-04|
|          | 4  | 0.00131 | 0.000005     | 0.000003       | 2.37E-05|
| Polyester| 4  | 0.00048 | 0.000009     | 0.000004       |         |
|          | 4  | 0.00034 | 0.000006     | 0.000003       | 2.07E-05|
|          | 4  | 0.00034 | 0.000008     | 0.000004       | 2.83E-06|
| Acrylic  | 4  | 0.00088 | 0.000009     | 0.000004       |         |
|          | 4  | 0.00086 | 0.000011     | 0.000006       | 0.007   |
|          | 4  | 0.00085 | 0.000006     | 0.000003       | 0.005   |
| Viscose  | 4  | 0.00048 | 0.000010     | 0.000005       |         |
|          | 4  | 0.00045 | 0.000004     | 0.000002       | 4.05E-04|
|          | 4  | 0.00044 | 0.000006     | 0.000003       | 2.44E-04|

YBK = Yarn before knitting, UPF = Unraveled yarn from plain knitted fabric, URF = Unraveled yarn from 1+1 rib knitted fabric. Level of significance at (P < 0.05)

### Table 4. Statistical analysis for yarn shearing

| Material | N  | Mean  | Std. Deviation | Std. Error Mean | p-value |
|----------|----|-------|----------------|-----------------|---------|
| Cotton   | 10 | 3.2789 | 0.00483       | 0.00153         |         |
|          | 10 | 3.0083 | 0.03786       | 0.01197         | 1.03E-09|
|          | 10 | 2.6830 | 0.06514       | 0.02060         | 1.95E-10|
| wool     | 10 | 3.1943 | 0.00537       | 0.00170         |         |
|          | 10 | 3.1180 | 0.06392       | 0.02021         | 0.002   |
|          | 10 | 1.6746 | 0.06531       | 0.02065         | 4.80E-14|
| Polyester| 10 | 5.9352 | 0.02205       | 0.00697         |         |
|          | 10 | 2.3350 | 0.07280       | 0.02302         | 8.34E-17|
|          | 10 | 1.1277 | 0.00895       | 0.00283         | 3.65E-23|
| Acrylic  | 10 | 4.0588 | 0.08202       | 0.02594         |         |
|          | 10 | 3.3515 | 0.05586       | 0.01767         | 5.27E-10|
|          | 10 | 3.1144 | 0.04152       | 0.01313         | 1.75E-10|
| Viscose  | 10 | 1.6637 | 0.04670       | 0.01477         |         |
|          | 10 | 1.1514 | 0.03247       | 0.01027         | 3.36E-11|
|          | 10 | 0.9822 | 0.02262       | 0.00715         | 4.32E-12|

YBK = Yarn before knitting, UPF = Unraveled yarn from plain knitted fabric, URF = Unraveled yarn from 1+1 rib knitted fabric. Level of significance at (P < 0.05)
Figure 13 depicts that the values of surface roughness (SMD) are increased for all the yarns unraveled from 1 x 1 rib followed by the yarns unraveled from plain-knitted fabrics, as compared to original yarns. The reason behind this fact is that the yarn remains in contact with various yarn tensioner devices, contact the mean values and statistical data which indicate that the significant change ($p < 0.05$) exists before and after the knitting actions/structures (plain knit and rib 1 x 1) for frictional and dynamic frictional coefficient values for all different types of yarn used in this study.

Figure 9. (a) Shear stress-strain curves for original yarns (b) Shear stress-strain curves for yarns unraveled from plain knitted fabrics (c) Shear stress-strain curves for yarns unraveled from 1×1 rib knitted fabrics.

Figure 10. Yarn shear moduli before knitting and after being unraveled

Figure 11. Static frictional coefficient ($\mu$) values before knitting and after being unraveled

Figure 13 depicts that the values of surface roughness (SMD) are increased for all the yarns unraveled from 1 x 1 rib followed by the yarns unraveled from plain-knitted fabrics, as compared to original yarns. The reason behind this fact is that the yarn remains in contact with various yarn tensioner devices, contact
points, and knitting elements, and thereafter, in the knitting action, yarn-to-needle and yarn-to-yarn interactions contribute to the increased values of surface roughness. The utmost increase in surface roughness (SMD) for unraveled yarn from the plain is 12.64% and 39.49% for yarn unraveled from 1 x 1 rib-knitted fabrics, as shown in Figure 13. The statistical data are given in Table 7 that implies the significant increase in surface roughness values after different knitting actions for all different types of yarn.

### 3.5. Microscopic images of yarns

To clarify the yarn damage more distinctly, optical microscopic analysis has been carried out as well. The knitting action damages the yarn structure, resulting in rupture of fibers, which causes short fibers to appear on the yarn surface. Figure 14 demonstrates the surface analysis of the original cotton, polyester, acrylic, wool, and viscose yarns, respectively. After the yarns being unraveled from the plain- and 1 x 1 rib-knitted fabrics, it can be observed that the number of protruded fibers from the yarns unraveled from the 1 x 1 rib is greater than those of unraveled from plain-knitted fabrics. Moreover, the yarns unraveled from the plain and 1 x 1 rib are untwisted to some extent. The degree of untwisting is higher for the yarns unraveled from 1 x 1 rib than that of yarn unraveled from the plain, as shown in Figures 14(k–o) and 14(f–j).

The shearing force by needle hook along the cross-section of the yarn acts as a cutting edge on the yarn surface, which shears off fibers from the yarn surface as confirmed by previous
4. Conclusions and future works

According to the analytical results, conclusions can be drawn as follows:

Studies that yarn drawing-out and deformation along the yarn cross-section result in yarn untwisting [19, 20]. Furthermore, from Figure 14(n), it can also be noticed that there is a pilling formation for the wool yarn unraveled from 1 x 1 rib-knitted fabrics due to its felting property.

Table 6. Statistical analysis for dynamic frictional coefficient of yarns

| Material | N | Mean | Std. Deviation | Std. Error Mean | p-value |
|----------|---|------|----------------|-----------------|---------|
| Cotton   | YBK 6 | 0.1817 | 0.00309 | 0.00126 | 0.008 |
|          | UPF 6 | 0.1953 | 0.00875 | 0.00357 | 0.000 |
|          | URF 6 | 0.2413 | 0.00543 | 0.00222 | 0.000 |
| wool     | YBK 6 | 0.2073 | 0.00251 | 0.00102 | 0.000 |
|          | UPF 6 | 0.2187 | 0.01057 | 0.00432 | 0.036 |
|          | URF 6 | 0.2310 | 0.00147 | 0.00060 | 0.000 |
| Polyester| YBK 6 | 0.1853 | 0.00449 | 0.00183 | 0.013 |
|          | UPF 6 | 0.1920 | 0.00397 | 0.00162 | 0.007 |
|          | URF 6 | 0.1993 | 0.00623 | 0.00254 | 0.000 |
| Acrylic  | YBK 6 | 0.2173 | 0.00383 | 0.00156 | 0.030 |
|          | UPF 6 | 0.2280 | 0.01130 | 0.00461 | 0.000 |
|          | URF 6 | 0.2307 | 0.00393 | 0.00160 | 0.025 |
| Viscose  | YBK 6 | 0.1680 | 0.00082 | 0.00033 | 0.000 |
|          | UPF 6 | 0.1757 | 0.00674 | 0.00275 | 0.000 |
|          | URF 6 | 0.1833 | 0.00257 | 0.00105 | 0.000 |

YBK = Yarn before knitting, UPF = Unraveled yarn from plain knitted fabric, URF = Unraveled yarn from 1+1 rib knitted fabric. Level of significance at (P < 0.05)

Table 7. Statistical analysis for surface roughness of yarns

| Material | N | Mean | Std. Deviation | Std. Error Mean | p-value |
|----------|---|------|----------------|-----------------|---------|
| Cotton   | YBK 6 | 2.2700 | 0.18921 | 0.07724 | 0.008 |
|          | UPF 6 | 2.5983 | 0.27025 | 0.11033 | 0.000 |
|          | URF 6 | 3.7517 | 0.00849 | 0.00347 | 0.000 |
| wool     | YBK 6 | 3.2483 | 0.03497 | 0.01427 | 0.019 |
|          | UPF 6 | 3.4733 | 0.20995 | 0.08571 | 0.001 |
|          | URF 6 | 3.7300 | 0.20317 | 0.08295 | 0.000 |
| Polyester| YBK 6 | 2.7983 | 0.04276 | 0.11299 | 0.034 |
|          | UPF 6 | 2.9333 | 0.10176 | 0.04613 | 0.003 |
|          | URF 6 | 2.9783 | 0.09966 | 0.04069 | 0.038 |
| Acrylic  | YBK 6 | 3.5417 | 0.04100 | 0.01674 | 0.000 |
|          | UPF 6 | 3.6367 | 0.07755 | 0.03166 | 0.001 |
|          | URF 6 | 3.8350 | 0.02713 | 0.01108 | 0.001 |
| Viscose  | YBK 6 | 2.0483 | 0.13477 | 0.05502 | 0.021 |
|          | UPF 6 | 2.2650 | 0.11983 | 0.04892 | 0.000 |
|          | URF 6 | 2.3100 | 0.02160 | 0.00882 | 0.001 |

YBK = Yarn before knitting, UPF = Unraveled yarn from plain knitted fabric, URF = Unraveled yarn from 1+1 rib knitted fabric. Level of significance at (P < 0.05)
Figure 14. Microscopic analysis of unraveled yarns as compared with the original yarns. (a, b, c, d, e) original cotton, polyester, acrylic, wool and viscose yarns, respectively. (f, g, h, i, j) unraveled yarns (cotton, polyester, acrylic, wool and viscose) from plain knitted fabrics. (k, l, m, n, o) unraveled yarns (cotton, polyester, acrylic, wool and viscose) from 1×1 rib knitted fabrics.
The impact of knitting actions for different knitting structures is significant, which leads to the obvious contraction in the mechanical properties of the unraveled yarn including tensile, bending and shearing in such an order that the degree of contraction for shearing modulus loss is the highest, followed by the bending modulus loss is in the middle and the tensile loss is the lowest. However, the knitting process can improve the elongation of the unraveled yarns, which endows more geometrical deformation to the knitted structure.

The knitting yarn damages are closely related to different knitted actions/structures and different raw materials. The yarns sustain diverse extents of tensile, bending, and shearing forces in different knitting actions/structures. Contrarily, different raw materials exhibit different mechanical and surface properties, resulting in varying degrees of loss based on the aforementioned properties.

Both the slope board methods and KES-FB4 are feasible and workable for evaluating the yarn surface properties in terms of static frictional coefficient testing and surface roughness (SMD) and dynamic frictional coefficient (MIU) testing, respectively.

The experimental methodology and analytical methods are effective and comprehensive for evaluating the yarn damages in the knitting process. The results in this article are of great importance for improving the quality of knitted articles, evaluating knitting yarns’ knittability, and in the development of high-performance technical textiles.

Future work should be carried on the high-speed circular knitting process, weaving process, and even braiding process, and so on, especially where the high-performance yarns, such as carbon, Kevlar, nano-fiber yarn, graphite yarn, are employed for technical application purposes because, in this case, the yarn damage should be particularly considered.

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