# Evaluating The Mechanical Stability of Cut-Resistant Woven Fabrics After Successive Laundering Cycles

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*Abstract*—**Repeated laundering is an important durability consideration for reusable protective textiles because washing may alter yarn arrangement, fabric compactness and the mechanical response of the textile structure. This study evaluates the effect of five and ten repeated washing cycles on the tensile strength, tearing strength and cut-resistance force (N) of twelve woven cut-resistant fabric constructions. The fabric set comprised FSS-25, FSS-50, FSS-75 and FGF-50 yarn systems, each produced in plain, twill and sateen weaves. Laundering was carried out in an IFB Elite VX front-loading washing machine using the laundering procedure adopted from AATCC LP1:2021, at 30°C for 30 minutes per cycle. Five independent replicate specimens were evaluated for each fabric construction and washing condition. Tensile and tear strength were evaluated in warp and weft directions, while cut resistance was evaluated as force. The mean percentage reductions, averaged across fabric constructions and measured directions, were 1.84% and 3.62% for tensile strength, 1.34% and 2.64% for tear strength, and 0.91% and 1.51% for cut-resistance force (N) after five and ten cycles, respectively. A three-factor factorial ANOVA (fabric code × weave × washing condition), conducted separately for each direction, showed a statistically significant washing-cycle effect on tensile strength and tear strength ($p < 0.001$), whereas the washing-cycle effect on cut-resistance force was not significant ($F(2,144) = 2.31$, $p = 0.103$). Fabric code and weave construction were significant sources of variation for all three properties. The findings indicate that the tested fabrics retained most of their measured mechanical performance after ten cycles, although modest reductions occurred in tensile and tear strength. Cut-resistance force is reported in newtons (N), and the same test methods were used before and after laundering.**

*Index Terms*—**Cut-Resistant Fabrics, Factorial ANOVA, Laundering, Mechanical Properties, Tear Strength, Tensile Strength, Woven Fabrics.**

## I. INTRODUCTION

Protective textiles are designed to provide resistance against mechanical hazards while maintaining acceptable flexibility, comfort and usability. Cut-resistant fabrics are used in applications where contact with sharp edges or blades may occur, including manufacturing, construction and other industrial activities. The development of protective textile structures therefore requires a balance between mechanical protection and the practical requirements of wearable materials [1–4, 9–12].

Composite yarns containing high-strength core materials and more flexible sheath fibres offer one route to this balance. Metal-wire and other hybrid yarns have been investigated for their physical and tensile properties, and their construction can influence the performance of the resulting textile [14–16]. In the baseline research associated with this study, stainless-steel wire and glass-fibre cores were combined with polyester and high-performance polyethylene sheath materials and woven into plain, twill and sateen structures [17].

Weave construction is an important structural variable because the interlacement frequency, float length and yarn mobility differ between plain, twill and sateen structures. Previous work discussed in the baseline paper reports that plain weave can provide compact interlacement and high fibre coverage, whereas twill and sateen constructions may provide different combinations of flexibility, yarn movement and cut resistance. The published literature also indicates that weave architecture and material composition can influence slicing and knife-related resistance [6–10, 13].

Protective gloves and other reusable textile products may undergo repeated laundering during their service life. Washing can potentially change the fabric

geometry, yarn packing, surface condition and the interaction between the core and sheath components. These changes may influence tensile strength, tear propagation and resistance to cutting. However, the baseline publication primarily compared the mechanical and functional properties of the unwashed fabric constructions; it did not report the present five- and ten-cycle laundering comparison [17].

The present work extends that baseline by examining the mechanical performance of the same family of woven cut-resistant fabrics after repeated laundering. The comparison is made between the initial condition and the conditions after five and ten washing cycles. The interpretation focuses on changes in measured mechanical properties and on whether washing condition, fabric code and weave construction have statistically significant effects.

Objective of the Study

The objective of this study is to investigate the effect of repeated laundering (five and ten washing cycles) on the mechanical performance of woven cut-resistant fabrics made from stainless-steel- and glass-fibre-core composite yarn systems. Specifically, the study aims to: (i) compare tensile strength in warp and weft directions before and after laundering; (ii) compare tearing strength in warp and weft directions before and after laundering; (iii) evaluate changes in cut-resistance force; and (iv) use factorial analysis of variance to determine the effects of fabric code, weave construction and washing condition on the measured responses.

## II. MATERIALS AND METHODS

### A. Fabric Materials and Construction

Twelve woven fabric constructions were considered. Four fabric-code groups were included: FSS-25, FSS-50 and FSS-75, representing stainless-steel-core composite yarn variants, and FGF-50, representing the glass-fibre-core variant. In the baseline publication, the stainless-steel wire diameters were identified as 0.025, 0.050 and 0.070 mm, respectively, while the glass-fibre core was 0.050 mm. Polyester and high-performance polyethylene were used as sheath materials in the composite yarn systems. Each fabric code was woven in three constructions: plain, twill and sateen [17].

Table I. Fabric codes, weave constructions and core-material groups.

| Fabric code | Weave construction | Core-material group |
|---|---|---|
| FSS-25 | Plain | Stainless-steel core |
| FSS-25 | Twill | Stainless-steel core |
| FSS-25 | Sateen | Stainless-steel core |
| FSS-50 | Plain | Stainless-steel core |
| FSS-50 | Twill | Stainless-steel core |
| FSS-50 | Sateen | Stainless-steel core |
| FSS-75 | Plain | Stainless-steel core |
| FSS-75 | Twill | Stainless-steel core |
| FSS-75 | Sateen | Stainless-steel core |
| FGF-50 | Plain | Glass-fibre core |
| FGF-50 | Twill | Glass-fibre core |
| FGF-50 | Sateen | Glass-fibre core |

### B. Laundering Procedure

Laundering was performed using an IFB Elite VX front-loading washing machine. The procedure was adopted as specified by the study as AATCC LP1:2021. The washing temperature was maintained at 30°C, and each washing cycle lasted 30 minutes. Two repeated-laundering conditions were investigated: five washing cycles and ten washing cycles. An initial, unwashed condition was used as the reference for comparison. Following the respective washing treatments, the woven fabrics were intended to be assessed for surface characteristics and mechanical performance. The supplied dataset contains the mechanical-property measurements; numerical surface-characterisation data were not supplied.

The detergent type and dosage, ballast/load, water-to-textile ratio, rinse and spin settings, drying procedure and conditioning atmosphere were not specified in the supplied experimental description. These details should be added to the final experimental record if available, because they are relevant to reproducibility and interpretation of laundering effects.

### C. Mechanical Testing and Response Variables

Three response variables were included: tensile strength, tearing strength and cut resistance. Tensile strength and tearing strength were recorded in both warp and weft directions. Cut resistance was recorded as force, with a corresponding protection level also shown in the summary section of the Excel workbook. The five replicate readings for each fabric construction

and condition were extracted from the replicate blocks in the supplied workbook.

The same testing methods and instrument settings were used to evaluate the fabrics before and after laundering. Tensile strength was determined in accordance with ASTM D5035 using an Instron 3365 universal testing machine operating on the constant-rate-of-extension principle, with 200 mm × 50 mm specimens and a test speed of 20 mm/min. Tearing strength was determined in accordance with ASTM D2261 using 8 in × 3 in specimens. Cut resistance was determined in accordance with BS EN ISO 13997. The cut-resistance force is reported in newtons (N).

D. Experimental Design and Replication

The study comprised a 4 × 3 × 3 factorial arrangements: four fabric codes, three weave constructions and three washing conditions (initial, five cycles and ten cycles). Five independent test specimens were evaluated for each fabric-code × weave × washing-condition combination. For tensile and tear strength, warp and weft responses were analysed separately. Cut-resistance force was analysed as a single response. Each directional tensile or tear analysis and the cut-resistance analysis therefore contained 180 observations.

E. Data Processing and Statistical Analysis

For each fabric construction and washing condition, the arithmetic mean and standard deviation were calculated from the five replicate observations. Percentage decrease relative to the initial condition was calculated as: percentage decrease = [(initial mean − washed mean) / initial mean] × 100. A three-factor factorial ANOVA was performed using fabric code, weave construction and washing condition as fixed factors. The model included all main effects and two- and three-factor interactions. Separate models were fitted for tensile-warp, tensile-weft, tear-warp, tear-weft and cut-resistance force. A significance level of $\alpha = 0.05$ was used. Partial eta-squared was calculated as an effect-size measure.

The ANOVA assumes independent observations, approximately normal model residuals and homogeneous variances. Levene's test was used to assess variance homogeneity and the Shapiro–Wilk test was used to assess residual normality. The factorial design was balanced, which generally provides some robustness to moderate departures from normality; nevertheless, the diagnostic results are reported as a limitation. The analysis treats the five readings in each condition as independent replicate specimens. This assumption should be confirmed from the laboratory sample records.

## III. RESULTS AND DISCUSSION

A. Overall Effect of Repeated Laundering

Table II. Mean percentage decrease in mechanical properties after five and ten laundering cycles.

| Mechanical property | Mean decrease after 5 cycles (%) | Mean decrease after 10 cycles (%) |
|---|---|---|
| Tensile strength | 1.84 | 3.62 |
| Tear strength | 1.34 | 2.64 |
| Cut resistance | 0.91 | 1.51 |

The overall cell-wise averages indicate that all three measured properties declined as the number of washing cycles increased. Tensile strength showed an average reduction of 1.84% after five cycles and 3.62% after ten cycles. Tear strength decreased by 1.34% and 2.64%, respectively. Cut-resistance force showed the smallest average reduction, at 0.91% after five cycles and 1.51% after ten cycles. These values are the unweighted averages of the percentage changes calculated for each fabric construction and, where applicable, each test direction. They describe the dataset and should not be interpreted as identical changes for every fabric.

B. Effect of Laundering on Tensile Strength

Tensile strength decreased progressively from the initial condition to five and ten washing cycles in the overall dataset. The mean tensile strength across all fabric constructions was 349.73 kgf in the warp direction and 276.73 kgf in the weft direction initially. After five cycles, the corresponding means were 343.21 kgf and 271.57 kgf; after ten cycles they were 336.93 kgf and 266.59 kgf. The average percentage reductions calculated across individual fabric-construction/direction means were 1.84% after five cycles and 3.62% after ten cycles.

The higher tensile values in the warp direction than in the weft direction were observed in the overall mean data. However, the magnitude of the difference varied by fabric code and weave construction. The fabric-code and weave effects were also statistically

significant, indicating that the baseline construction remained an important determinant of tensile performance. The progressive reduction with washing suggests a modest change in the load-bearing response of the woven structures. The present dataset does not include direct measurements of yarn slippage, shrinkage or structural distortion, so these possible mechanisms cannot be established from the mechanical results alone.

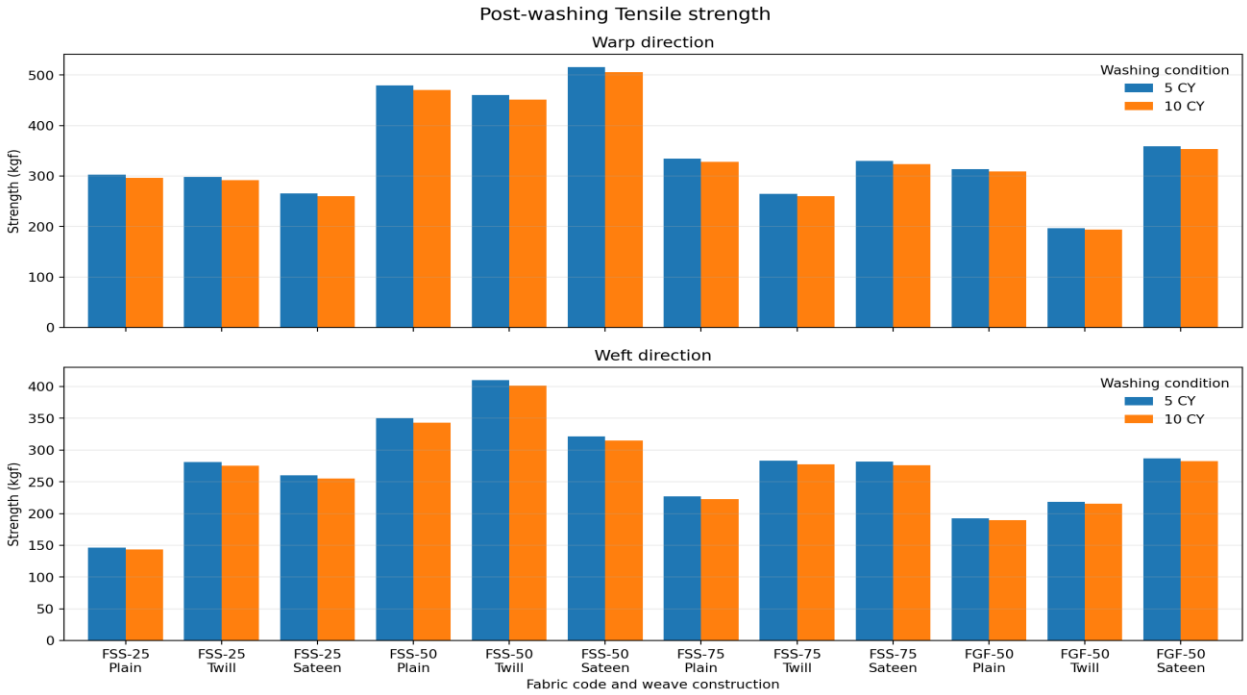



Fig. 1. Post-washing tensile strength for all twelve fabric constructions.

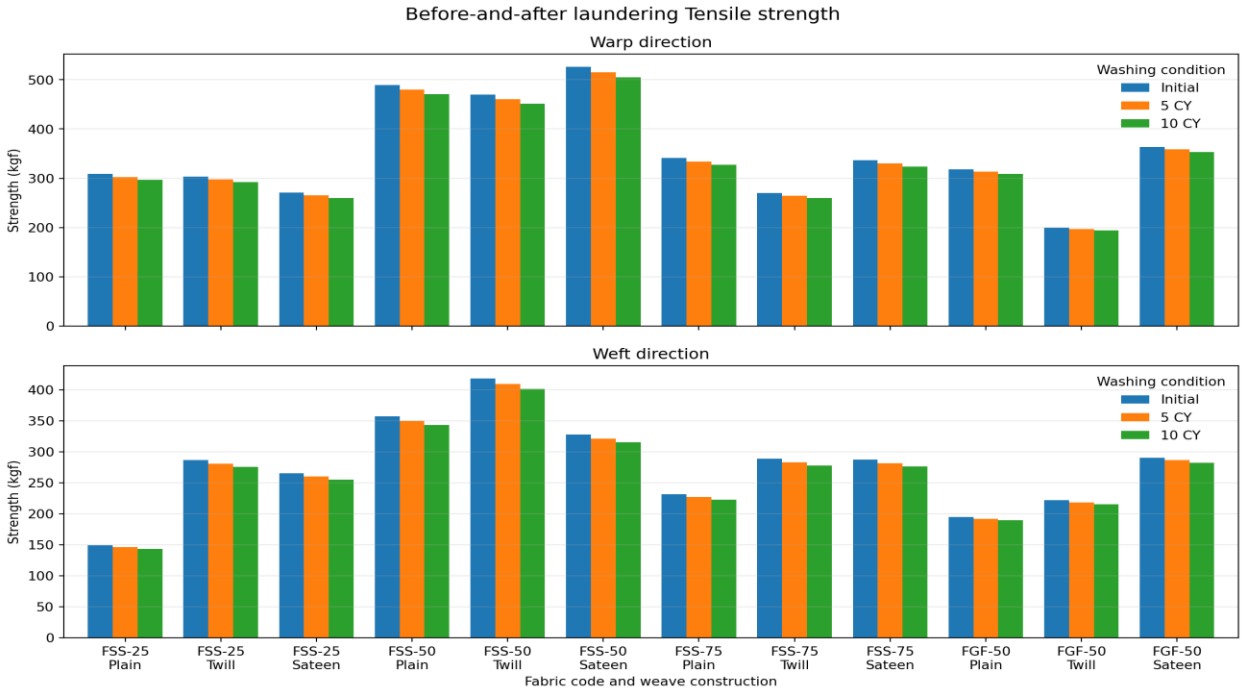



Fig. 2. Before-and-after tensile strength for all twelve fabric constructions.

Table III. Tensile strength in the warp and weft directions under each washing condition.

| Fabric | Weave | Warp initial | Warp 5 CY | Warp 10 CY | Weft initial | Weft 5 CY | Weft 10 CY |
|---|---|---|---|---|---|---|---|
| FSS-25 | Plain | 308.50 ± 6.88 | 302.40 ± 11.87 | 296.50 ± 12.75 | 149.20 ± 5.31 | 146.20 ± 4.35 | 143.40 ± 5.07 |
| FSS-25 | Twill | 303.70 ± 8.69 | 297.70 ± 9.36 | 291.90 ± 11.33 | 286.80 ± 8.75 | 281.10 ± 10.43 | 275.60 ± 9.41 |
| FSS-25 | Sateen | 270.70 ± 8.84 | 265.30 ± 7.93 | 260.10 ± 7.93 | 265.30 ± 12.06 | 260.00 ± 7.93 | 254.90 ± 7.93 |
| FSS-50 | Plain | 489.40 ± 14.94 | 479.70 ± 19.62 | 470.30 ± 19.62 | 357.30 ± 12.46 | 350.20 ± 19.62 | 343.40 ± 19.62 |
| FSS-50 | Twill | 469.90 ± 18.90 | 460.60 ± 14.74 | 451.60 ± 14.74 | 418.10 ± 14.23 | 409.80 ± 14.74 | 401.80 ± 14.74 |
| FSS-50 | Sateen | 525.70 ± 20.45 | 515.20 ± 19.10 | 505.20 ± 19.10 | 328.10 ± 12.34 | 321.60 ± 19.10 | 315.30 ± 19.10 |
| FSS-75 | Plain | 340.90 ± 12.99 | 334.10 ± 13.06 | 327.60 ± 13.06 | 232.00 ± 8.18 | 227.40 ± 13.06 | 222.90 ± 13.06 |
| FSS-75 | Twill | 270.20 ± 8.23 | 264.80 ± 9.77 | 259.70 ± 9.77 | 289.10 ± 10.35 | 283.30 ± 9.77 | 277.80 ± 9.77 |
| FSS-75 | Sateen | 336.80 ± 13.45 | 330.10 ± 10.90 | 323.70 ± 10.90 | 287.50 ± 9.94 | 281.80 ± 10.90 | 276.30 ± 10.90 |
| FGF-50 | Plain | 317.90 ± 12.41 | 313.40 ± 10.53 | 309.10 ± 10.53 | 194.80 ± 6.94 | 192.10 ± 10.53 | 189.40 ± 10.53 |
| FGF-50 | Twill | 199.60 ± 9.23 | 196.80 ± 7.09 | 194.10 ± 7.09 | 221.80 ± 7.11 | 218.70 ± 7.09 | 215.70 ± 7.09 |
| FGF-50 | Sateen | 363.50 ± 14.22 | 358.40 ± 10.96 | 353.40 ± 10.96 | 290.70 ± 10.02 | 286.60 ± 10.96 | 282.60 ± 10.96 |

C. Effect of Laundering on Tear Strength

Tear strength also declined with repeated laundering. Across the twelve fabric constructions, the overall mean warp tear strength decreased from 121.39 kgf initially to 119.65 kgf after five cycles and 117.96 kgf after ten cycles. The corresponding weft values decreased from 131.95 kgf to 130.34 kgf and 128.77 kgf. Averaged across the fabric-construction/direction means, the reductions were 1.34% after five cycles and 2.64% after ten cycles.

The weft-direction overall mean was higher than the warp-direction mean in the supplied dataset, although individual fabric constructions showed different directional responses. The fabric code and weave construction had strong effects on tear strength, and the washing-cycle effect was statistically significant in both directions. The data therefore indicate a small but statistically detectable decline in tearing performance after repeated washing. As with tensile strength, the specific structural mechanism responsible for this change cannot be identified without additional measurements of fabric dimensions, yarn mobility or post-wash microstructure.

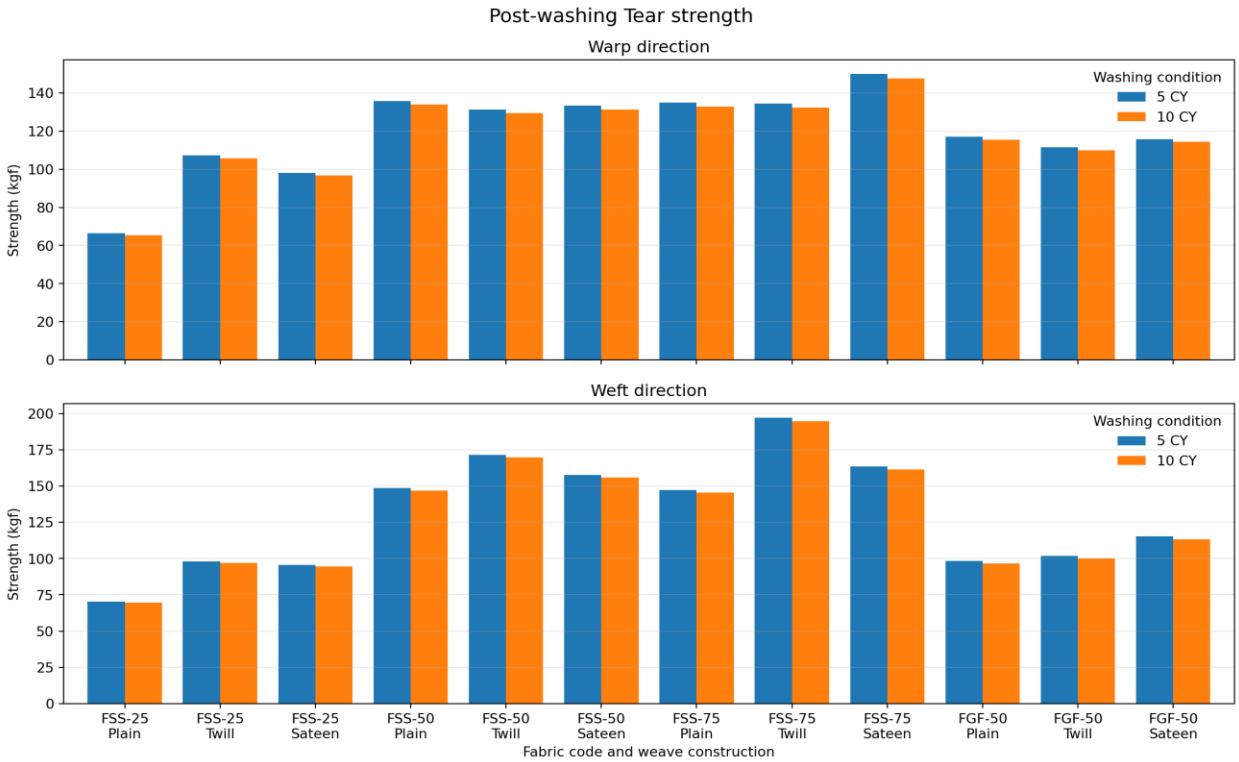



Fig. 3. Post-washing tear strength for all twelve fabric constructions.

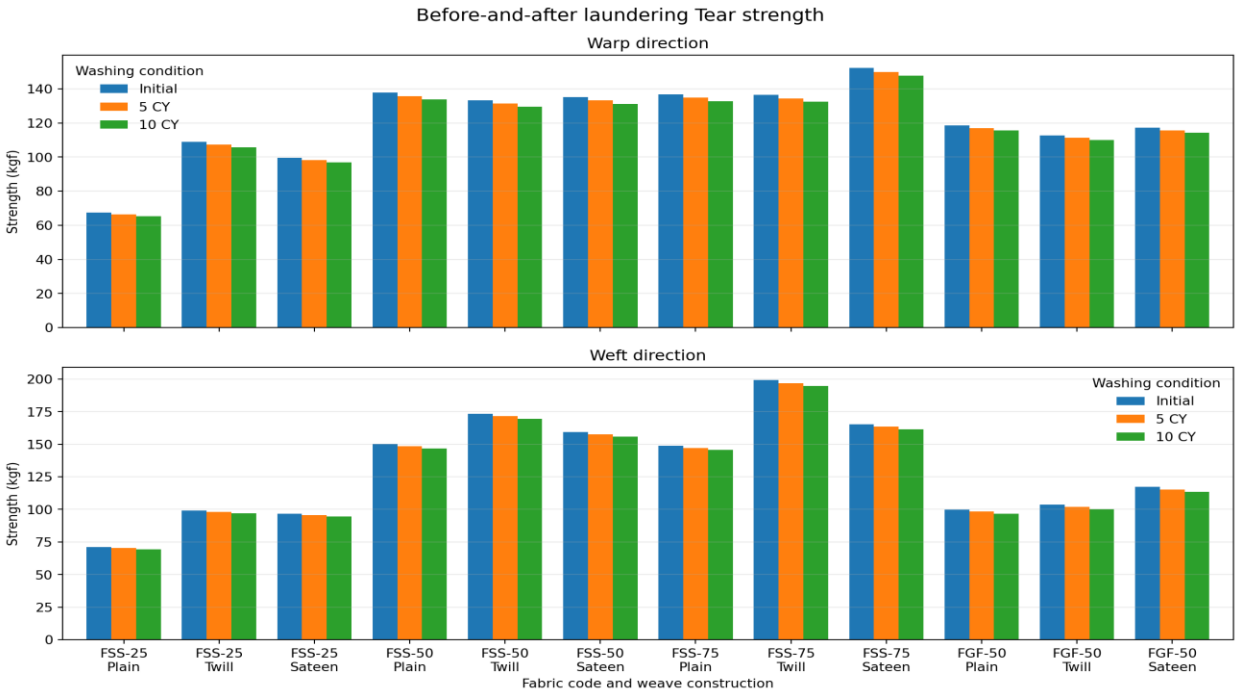



Fig. 4. Before-and-after tear strength for all twelve fabric constructions.

Table IV. Tear strength in the warp and weft directions under each washing condition.

| Fabric | Weave | Warp initial | Warp 5 CY | Warp 10 CY | Weft initial | Weft 5 CY | Weft 10 CY |
|---|---|---|---|---|---|---|---|
| FSS-25 | Plain | 67.40 ± 2.59 | 66.40 ± 2.00 | 65.40 ± 2.00 | 71.10 ± 3.06 | 70.30 ± 2.00 | 69.50 ± 2.00 |
| FSS-25 | Twill | 109.00 ± 4.05 | 107.40 ± 3.84 | 105.80 ± 3.84 | 99.10 ± 3.78 | 98.00 ± 3.84 | 96.90 ± 3.84 |
| FSS-25 | Sateen | 99.70 ± 3.33 | 98.20 ± 4.05 | 96.80 ± 4.05 | 96.60 ± 2.72 | 95.50 ± 4.05 | 94.50 ± 4.05 |
| FSS-50 | Plain | 137.90 ± 5.46 | 135.80 ± 3.93 | 133.80 ± 3.93 | 150.10 ± 4.73 | 148.40 ± 3.93 | 146.80 ± 3.93 |
| FSS-50 | Twill | 133.40 ± 4.78 | 131.40 ± 6.12 | 129.50 ± 6.12 | 173.40 ± 5.97 | 171.50 ± 6.12 | 169.60 ± 6.12 |
| FSS-50 | Sateen | 135.30 ± 5.53 | 133.30 ± 4.30 | 131.30 ± 4.30 | 159.30 ± 6.30 | 157.50 ± 4.30 | 155.80 ± 4.30 |
| FSS-75 | Plain | 136.90 ± 3.93 | 134.90 ± 4.23 | 132.90 ± 4.23 | 148.90 ± 4.88 | 147.20 ± 4.23 | 145.60 ± 4.23 |
| FSS-75 | Twill | 136.40 ± 5.47 | 134.40 ± 4.90 | 132.40 ± 4.90 | 199.10 ± 6.92 | 196.90 ± 4.90 | 194.70 ± 4.90 |
| FSS-75 | Sateen | 152.20 ± 5.24 | 149.90 ± 4.84 | 147.70 ± 4.84 | 165.20 ± 5.62 | 163.40 ± 4.84 | 161.50 ± 4.84 |
| FGF-50 | Plain | 118.50 ± 4.03 | 117.00 ± 3.95 | 115.60 ± 3.95 | 99.90 ± 3.38 | 98.30 ± 3.95 | 96.70 ± 3.95 |
| FGF-50 | Twill | 112.80 ± 3.95 | 111.40 ± 3.86 | 110.00 ± 3.86 | 103.50 ± 3.15 | 101.80 ± 3.86 | 100.20 ± 3.86 |
| FGF-50 | Sateen | 117.20 ± 4.31 | 115.70 ± 5.34 | 114.30 ± 5.34 | 117.20 ± 4.30 | 115.30 ± 5.34 | 113.40 ± 5.34 |

D. Effect of Laundering on Cut Resistance

The overall mean cut-resistance force decreased from 26.67 in the initial condition to 26.43 after five cycles and 26.28 after ten cycles, with force expressed in newtons (N). The average percentage reduction across the twelve fabric constructions was 0.91% after five cycles and 1.51% after ten cycles. The reduction was smaller than the corresponding average reductions in tensile and tear strength.

The fabric code and weave construction had statistically significant effects on cut-resistance force, while the main effect of washing condition was not statistically significant at the 5% level. Thus, the observed numerical decrease in cut-resistance force should not be described as a statistically demonstrated laundering effect in this dataset. The protection-level labels shown in the worksheet remained unchanged across the three conditions for most fabric constructions; the FGF-50 twill sample was recorded as Level E, while the other FGF-50 constructions were recorded as Level D and Level F as applicable. The level classifications should be checked against the correct standard edition and the current test records.

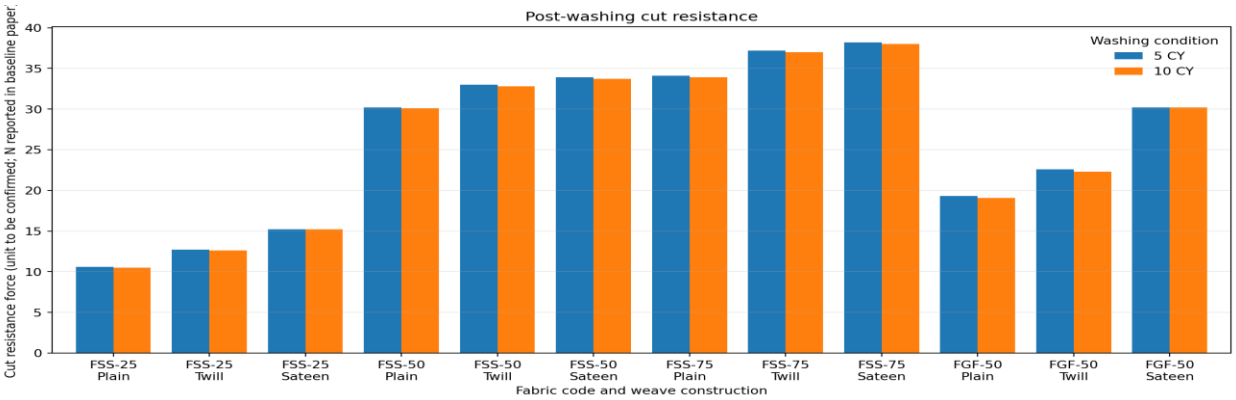



Fig. 5. Post-washing cut resistance for all twelve fabric constructions.

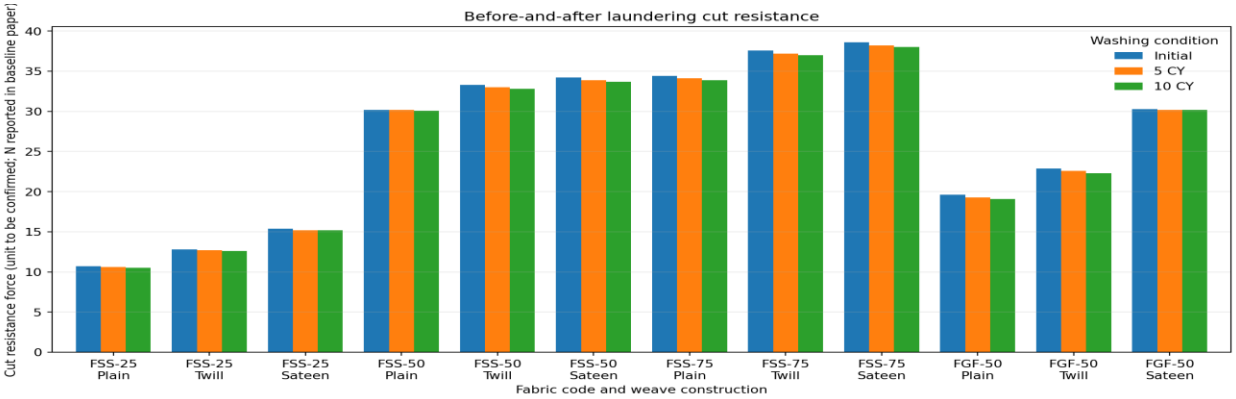



Fig. 6. Before-and-after cut resistance for all twelve fabric constructions.

Table V. Cut-resistance force and percentage decrease after laundering.

| Fabric | Weave | Initial force | 5 CY force | 10 CY force | Decrease 5 CY (%) | Decrease 10 CY (%) |
|---|---|---|---|---|---|---|
| FSS-25 | Plain | 10.70 ± 0.37 | 10.60 ± 0.42 | 10.50 ± 0.42 | 0.93 | 1.87 |
| FSS-25 | Twill | 12.80 ± 0.49 | 12.70 ± 0.51 | 12.60 ± 0.55 | 0.78 | 1.56 |
| FSS-25 | Sateen | 15.40 ± 0.64 | 15.20 ± 0.50 | 15.20 ± 0.49 | 1.30 | 1.30 |
| FSS-50 | Plain | 30.20 ± 1.26 | 30.20 ± 1.17 | 30.10 ± 1.25 | 0.00 | 0.33 |
| FSS-50 | Twill | 33.30 ± 1.03 | 33.00 ± 1.40 | 32.80 ± 1.40 | 0.90 | 1.50 |
| FSS-50 | Sateen | 34.20 ± 1.06 | 33.90 ± 1.40 | 33.70 ± 1.40 | 0.88 | 1.46 |
| FSS-75 | Plain | 34.40 ± 1.12 | 34.10 ± 1.10 | 33.90 ± 1.10 | 0.87 | 1.45 |
| FSS-75 | Twill | 37.60 ± 1.33 | 37.20 ± 1.10 | 37.00 ± 1.10 | 1.06 | 1.60 |
| FSS-75 | Sateen | 38.60 ± 1.22 | 38.20 ± 1.38 | 38.00 ± 1.29 | 1.04 | 1.55 |
| FGF-50 | Plain | 19.60 ± 0.60 | 19.30 ± 0.59 | 19.10 ± 0.59 | 1.53 | 2.55 |
| FGF-50 | Twill | 22.90 ± 0.66 | 22.60 ± 0.59 | 22.30 ± 0.59 | 1.31 | 2.62 |
| FGF-50 | Sateen | 30.30 ± 0.98 | 30.20 ± 1.06 | 30.20 ± 0.99 | 0.33 | 0.33 |

## IV. ANOVA ANALYSIS

A three-factor factorial ANOVA was applied to determine the effects of fabric code, weave construction and washing condition. Tensile and tear responses were analysed separately for warp and weft directions, while cut resistance was analysed as force. Each model included the three main effects and all interaction terms. The design was balanced, with five replicate observations in each fabric-code × weave × washing-condition cell.

Table VI. Factorial ANOVA results for fabric code, weave construction and washing condition.

| Response | Direction | Effect | df | F | p-value | Partial $\eta^2$ |
|---|---|---|---|---|---|---|
| Tensile strength | Warp | Fabric code | 3 | 2457.549 | <0.001 | 0.981 |
| Tensile strength | Warp | Weave construction | 2 | 405.611 | <0.001 | 0.849 |
| Tensile strength | Warp | Washing condition | 2 | 14.821 | <0.001 | 0.171 |
| Tensile strength | Warp | Fabric code × weave | 6 | 155.682 | <0.001 | 0.866 |
| Tensile strength | Warp | Fabric code × washing | 6 | 0.498 | 0.8091 | 0.020 |
| Tensile strength | Warp | Weave × washing | 4 | 0.037 | 0.9973 | 0.001 |
| Tensile strength | Warp | Fabric × weave × washing | 12 | 0.012 | 1.0000 | 0.001 |
| Tensile strength | Weft | Fabric code | 3 | 1255.072 | <0.001 | 0.963 |
| Tensile strength | Weft | Weave construction | 2 | 617.063 | <0.001 | 0.896 |
| Tensile strength | Weft | Washing condition | 2 | 11.397 | <0.001 | 0.137 |
| Tensile strength | Weft | Fabric code × weave | 6 | 189.536 | <0.001 | 0.888 |
| Tensile strength | Weft | Fabric code × washing | 6 | 0.294 | 0.9391 | 0.012 |
| Tensile strength | Weft | Weave × washing | 4 | 0.073 | 0.9902 | 0.002 |
| Tensile strength | Weft | Fabric × weave × washing | 12 | 0.023 | 1.0000 | 0.002 |
| Tear strength | Warp | Fabric code | 3 | 1122.133 | <0.001 | 0.959 |
| Tear strength | Warp | Weave construction | 2 | 94.094 | <0.001 | 0.567 |
| Tear strength | Warp | Washing condition | 2 | 9.061 | <0.001 | 0.112 |
| Tear strength | Warp | Fabric code × weave | 6 | 110.722 | <0.001 | 0.822 |
| Tear strength | Warp | Fabric code × washing | 6 | 0.110 | 0.9952 | 0.005 |
| Tear strength | Warp | Weave × washing | 4 | 0.007 | 0.9999 | 0.000 |
| Tear strength | Warp | Fabric × weave × washing | 12 | 0.008 | 1.0000 | 0.001 |
| Tear strength | Weft | Fabric code | 3 | 3510.874 | <0.001 | 0.987 |
| Tear strength | Weft | Weave construction | 2 | 511.938 | <0.001 | 0.877 |
| Tear strength | Weft | Washing condition | 2 | 7.459 | <0.001 | 0.094 |
| Tear strength | Weft | Fabric code × weave | 6 | 97.366 | <0.001 | 0.802 |
| Tear strength | Weft | Fabric code × washing | 6 | 0.126 | 0.9931 | 0.005 |
| Tear strength | Weft | Weave × washing | 4 | 0.022 | 0.9991 | 0.001 |
| Tear strength | Weft | Fabric × weave × washing | 12 | 0.005 | 1.0000 | 0.000 |
| Cut resistance | Cut force | Fabric code | 3 | 5066.522 | <0.001 | 0.991 |
| Cut resistance | Cut force | Weave construction | 2 | 532.135 | <0.001 | 0.881 |
| Cut resistance | Cut force | Washing condition | 2 | 2.307 | 0.1032 | 0.031 |
| Cut resistance | Cut force | Fabric code × weave | 6 | 55.872 | <0.001 | 0.700 |
| Cut resistance | Cut force | Fabric code × washing | 6 | 0.092 | 0.9971 | 0.004 |
| Cut resistance | Cut force | Weave × washing | 4 | 0.040 | 0.9969 | 0.001 |
| Cut resistance | Cut force | Fabric × weave × washing | 12 | 0.046 | 1.0000 | 0.004 |

The washing-condition main effect was statistically significant for tensile strength in the warp direction ($F(2,144) = 14.82$, $p < 0.001$, partial $\eta^2 = 0.171$) and weft direction ($F(2,144) = 11.40$, $p < 0.001$, partial $\eta^2 = 0.137$). It was also significant for tear strength in the warp direction ($F(2,144) = 9.06$, $p < 0.001$, partial $\eta^2 = 0.112$) and weft direction ($F(2,144) = 7.46$, $p < 0.001$, partial $\eta^2 = 0.094$). In contrast, washing condition did not have a statistically significant main effect on cut-resistance force ($F(2,144) = 2.31$, $p = 0.103$, partial $\eta^2 = 0.031$).

Fabric code and weave construction were statistically significant for all five analysed responses ($p < 0.001$). The fabric-code × weave interaction was also significant for each response ($p < 0.001$), indicating that the effect of weave construction differed across fabric-code groups. Interactions involving washing condition were not statistically significant in these models ($p > 0.05$). This pattern suggests that the measured differences among fabric systems and weave structures were substantial, while the laundering-related changes were comparatively small and broadly similar across the tested constructions.

Model diagnostics showed no evidence of unequal variances by Levene's test for any response (all $p > 0.54$). Shapiro–Wilk tests indicated residual

departures from normality for tear strength in both directions and for cut-resistance force ($p < 0.05$); tensile residuals did not show significant departures. Given the balanced design and similar group sizes, the ANOVA is presented as the planned factorial analysis, but the tear and cut-resistance p-values should be interpreted with this diagnostic limitation in mind. A robust or permutation-based sensitivity analysis would strengthen the statistical reporting.

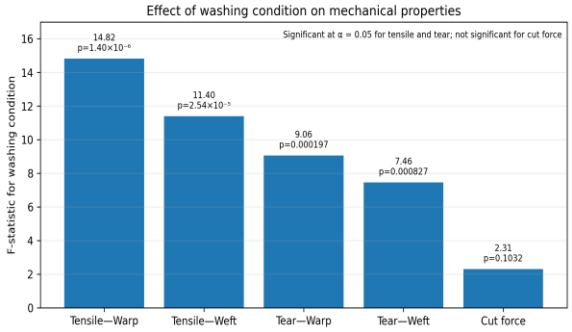



Fig. 7. F-statistics and p-values for the washing-condition main effect across the five response variables.

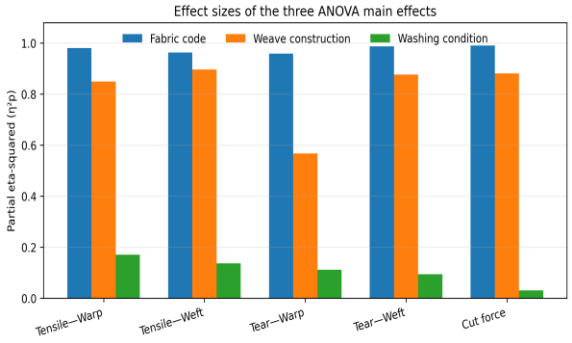



Fig. 8. Partial eta-squared effect sizes for fabric code, weave construction and washing condition.

## V. CONCLUSION

This study evaluated the effect of repeated laundering on tensile strength, tear strength and cut-resistance force in twelve woven cut-resistant fabric constructions made from stainless-steel- and glass-fibre-core composite yarn systems. The supplied data showed a progressive reduction in all three measured properties from the initial condition to five and ten washing cycles. The average reductions after ten cycles were 3.62% for tensile strength, 2.64% for tear strength and 1.51% for cut-resistance force.

Factorial ANOVA demonstrated statistically significant washing-condition effects on tensile and tear strength in both warp and weft directions. The washing-condition effect on cut-resistance force was not statistically significant at $\alpha = 0.05$. Fabric code, weave construction and their interaction were significant for all analysed mechanical responses, confirming that the underlying fabric system and weave architecture were important determinants of performance.

Within the tested conditions, the woven cut-resistant fabrics retained most of their measured mechanical performance after ten laundering cycles. Nevertheless, the reductions in tensile and tear strength indicate that repeated washing should be considered when assessing the durability of reusable protective textiles. The present conclusions are limited to the supplied dataset and the specified laundering conditions. The findings are limited to the specified laundering conditions; detergent dosage, drying procedure and conditioning atmosphere should be documented in future reporting to support full reproducibility. The dataset contained mechanical test results only; therefore, no quantitative surface-characterization results are presented.

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