

Impact of Irregular Reed Denting Patterns on Fabric Width in Woven Structures

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Abstract

This study investigates the structural effects of irregular denting arrangements in the reed—formed by intentionally left empty dents—on fabric width, warp crimp, and weft crimp, together with variations in weave type and weft density. In hybrid woven fabrics constructed using five weave structures and three weft densities, the proportion of empty dents in the reed was systematically varied and yarn crimp behavior was quantitatively analyzed. The results indicate that weft density is a strong determinant of both warp and weft crimp, while reed emptiness significantly increases fabric width. Clear differences in warp crimp were observed among the investigated weave types: leno-based structures exhibited higher warp crimp values, whereas the plain-weave and straight-float structures produced lower values. Overall, the findings demonstrate that irregular reed denting, in combination with weave structure and yarn density, substantially alters fabric geometry. The findings identify reed design as a strategic parameter for controlling fabric width, yarn crimp behavior, and dimensional stability in woven production. Predicting the dimensional changes arising from the combined effects of reed design and fabric construction can support production planning in subsequent finishing and garment manufacturing processes, reduce dimensional inconsistencies and material losses, and improve the conformity of the final product to the intended design specifications. Maintaining the intended dimensions and shape of the final product after production and throughout its service life can also contribute to consistent product quality and help meet user expectations. In this respect, the study provides a novel contribution to the limited literature on irregular reed denting.

Keywords: Reed denting; Yarn crimp; Fabric width; Hybrid leno structures; Woven fabric geometry.

1. INTRODUCTION

The dimensional properties of woven fabrics, such as width, length, and thickness, are governed primarily by the geometry of yarn movement, which is determined by weave structure, yarn density, and reed configuration [1]. Variations in these structural parameters influence fabric geometry, thereby affecting process stability and final-product performance. Among these properties, fabric width is a critical quality characteristic in weaving and garment manufacturing because variations in width can significantly affect cutting efficiency, production costs, and



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Cite: Kastacı, B. B. (2026). Impact of irregular reed denting patterns on fabric width in woven structures. *International Journal of New Findings in Engineering, Science and Technology*, 4(2), 14-25. <https://doi.org/10.61150/ijonfest.2012861>

dimensional consistency. Therefore, understanding the structural mechanisms that control fabric width is important for woven-fabric design and process optimization.

Fabric width is closely associated with yarn crimp, which results from the curved paths followed by warp and weft yarns within the woven structure. Yarn crimp is influenced by interlacement frequency, float length, yarn interactions, and the balance of forces generated during weaving. In addition to weave type and yarn density, fabric geometry is affected by yarn mechanical properties, including yarn diameter, rigidity, extensibility, and compressibility, as well as weaving tension conditions. Comprehensive treatments of woven textile engineering describe weave structure, thread density, yarn crimp, and yarn properties as interdependent parameters governing fabric dimensions and structural behavior [2,3]. Experimental observations have further demonstrated that yarn cross-sectional geometry varies along the yarn path and that yarn linear density, twist factor, and warp and weft cover factors influence yarn deformation within woven fabrics [4]. The curved configuration of the yarns results from the equilibrium between yarn rigidity and external forces, which determines crimp formation. Furthermore, post-weaving dimensional relaxation demonstrates that woven-fabric geometry is dynamic and tension-dependent [5]. Subsequent studies have emphasized that fabric geometry should be regarded not only as a theoretical modeling problem but also as a design parameter directly associated with fabric performance and dimensional stability [6]. In this context, weave structure, yarn density, and yarn arrangement within the fabric collectively influence both mechanical behavior and dimensional characteristics. Recent experimental research has also shown that warp crimp distribution across the fabric width is closely associated with the selected structural solution and fabric-setting parameters [7].

The mathematical and physical principles of woven fabric geometry were initially introduced by Peirce [8], who proposed fundamental geometrical models describing yarn arrangement within woven structures. Hamilton extended the principles of plain-weave geometry established by Peirce and Kemp to other weave structures and proposed a general system of geometry applicable to different types of woven fabrics [9]. Experimental studies have demonstrated that increasing yarn density restricts the available space for yarns within the woven structure, resulting in increased yarn waviness and consequently higher yarn crimp values [10]. Similarly, the interlacement frequency and float length associated with different weave structures have been widely recognized as major factors affecting yarn path geometry and crimp behavior. A recent review further identified weave structure as a primary structural factor governing yarn crimp and the physical characteristics of woven fabrics [11]. More recently, an analytical and experimental study reported that thread crimp increases with the number of yarn transitions and emphasized its practical importance in determining actual fabric width, reed width, and reed number [12].

In woven-fabric production, the reed-denting plan determines the distribution of warp yarns among the reed dents and is one of the principal production parameters controlling warp arrangement and yarn spacing. Previous studies have demonstrated that weave geometry, yarn arrangement, and other structural parameters play significant roles in determining yarn crimp behavior and fabric geometry [13]. In the broader context of weave design, modifications to drafting and lifting arrangements have also been shown to alter yarn organization and generate different surface configurations, even when the same basic weave is retained [14]. However, most existing studies have focused on homogeneous and symmetrical denting arrangements, whereas irregular denting systems produced by intentionally leaving dents empty have not been systematically investigated.

Recent studies have also introduced statistical and data-driven modeling approaches for predicting fabric geometry and yarn crimp behavior. Multivariate analyses and artificial intelligence-based models have been employed to evaluate the relationships between weave structure, yarn density, production parameters, and fabric properties [15, 16]. Nevertheless, these studies generally treated reed denting parameters as fixed conditions or excluded them from the analysis.

The literature indicates that, although the relationships among weave structure, yarn density, and yarn crimp have been extensively investigated, the combined influence of irregular reed denting arrangements, weave type, and weft density on fabric width and yarn crimp behavior has not been directly addressed. This represents an important research gap in the literature on woven-fabric geometry.

In the present study, five woven structures were examined: one plain-weave structure and four hybrid structures comprising plain weave–leno and plain weave–straight-float combinations. These hybrid constructions enabled yarn behavior to be evaluated across a broader structural framework representing different interlacement characteristics. With yarn count held constant, weft density and the proportion of empty dents in the reed were systematically varied. Accordingly, the combined influence of irregular reed denting, weave structure, and weft density on fabric width, warp

crimp, and weft crimp was examined using a multidimensional experimental design. The novelty of this study lies in treating irregular reed denting as a structural design variable and quantitatively evaluating its combined influence with weave type and weft density on fabric width and yarn crimp. Within this framework, particular attention was given to the spiral movement of warp yarns in leno structures under irregular reed-denting conditions [17]. In addition to conventional statistical analyses, three-dimensional scatter plots were used to visualize the patterns associated with weave structure, weft density, and empty-dent ratio in relation to woven-fabric geometry. The findings contribute to understanding reed denting not only as a production parameter but also as a structural design variable influencing woven-fabric geometry.

2. MATERIALS AND METHODS

2.1 Materials

In the experimental study, Ne 40/2 combed cotton yarns from the same lot were used in both the warp and weft systems. The yarns in both directions had a twist level of 650 turns/m and an S-twist direction. All fabric samples were woven under identical warp-tension, warp-let-off, and weft-insertion conditions to isolate the effects of weave structure and variations in reed denting.

The samples were produced on a Smith G6300 dobby weaving machine equipped with six harness frames. During weaving, a rotary doup system was used to form the leno interlacements. Both the ground weave and the hybrid regions containing leno interlacements and straight floats were woven simultaneously within the same warp system [16].

2.2 Experimental Design and Weave Structures

In this study, different hybrid weave combinations incorporated into a plain-weave ground structure were investigated in terms of fabric geometry and structural behavior. A total of five weave constructions were designed:

- 3/3 leno–plain weave hybrid structure (Weave Code: 1),
- 3/3 straight-float–plain weave hybrid structure (Weave Code: 2),
- 5/5 leno–plain weave hybrid structure (Weave Code: 3),
- 5/5 straight-float–plain weave hybrid structure (Weave Code: 4),
- 1/1 plain weave structure used as the reference sample (Weave Code: 5).

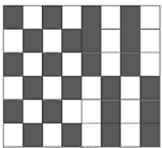
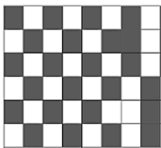
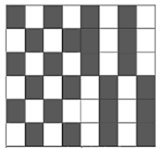
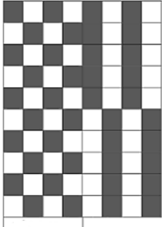
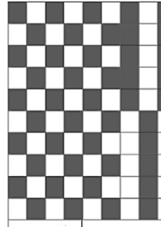
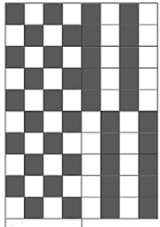
Float Length	Narrow Pattern Interval	Medium Pattern Interval	Wide Pattern Interval
3	 x3 repeats	 x7 repeats	 x15 repeats
5	 x3 repeats	 x7 repeats	 x15 repeats

Figure 1. Weave structures designed according to different pattern intervals.

Each hybrid weave structure was additionally produced in three different pattern intervals (narrow, medium, and wide). Each weave type was designed in three groups according to pattern interval variations (Figure 1).

The plain-weave structure was used as the ground weave in all fabric samples. In the leno-based hybrid structures, the warp yarns crossed and twisted within specific regions, creating an interlocking effect between the yarns and enhancing structural stability. In contrast, in the straight-float hybrid structures, the warp yarns extended across the 3/3 or 5/5 float regions without twisting and followed a conventional float path. Consequently, these structures provided less yarn binding than the leno hybrids, contributing to differences in weft-yarn crimp and fabric-width behavior.

2.3 Reed Denting Plans

The reed-denting plans were designed at three spacing levels in accordance with the weave structures. In all samples, the ground warp yarns were dented at a rate of two ends per dent. In the hybrid weave regions, selected dents were intentionally left empty, creating zones with different warp-yarn distributions across the reed. Consequently, the yarns were guided through the reed at different intervals, thereby influencing the crimp behavior of both the warp and weft yarns.

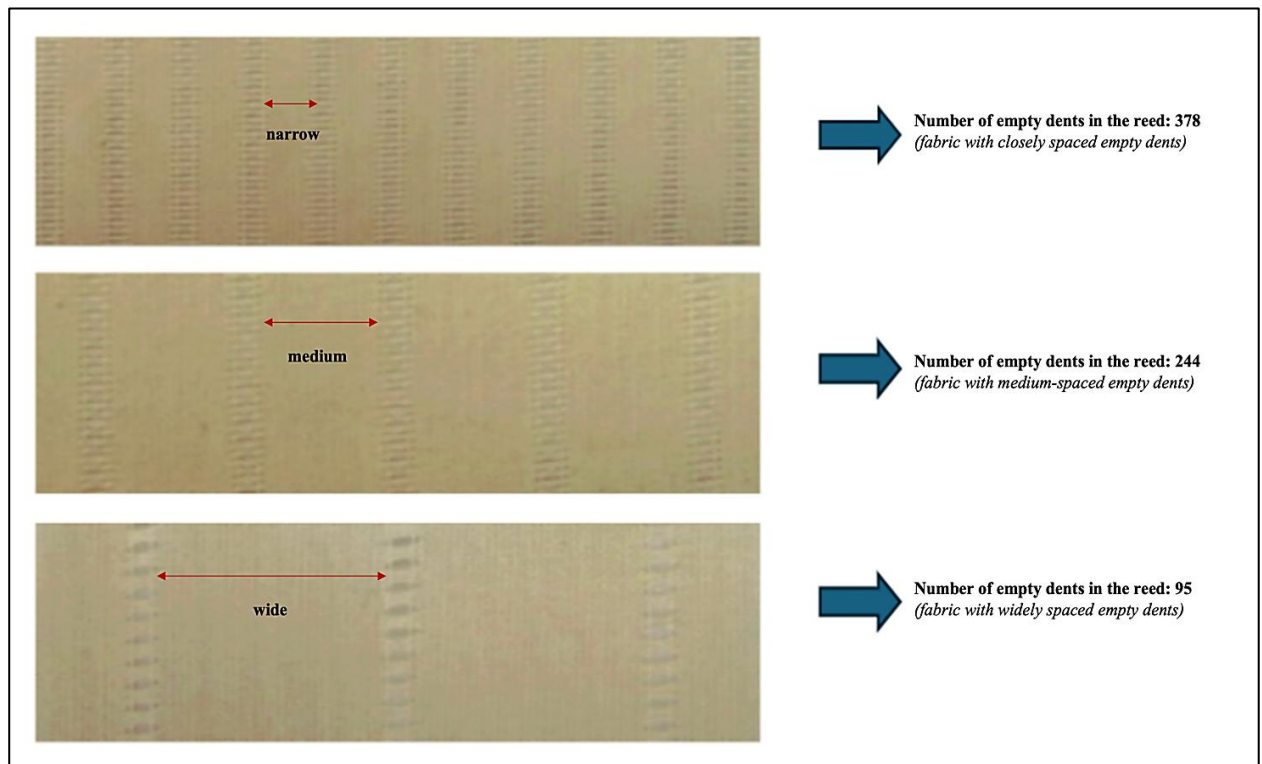


Figure 2. Fabric appearances obtained from different irregular reed denting arrangements.

- Reed Plan No: (90/1.88)

Low-spacing irregular denting plan. Within each 34-dent section, two dents were left empty, corresponding to an empty-dent proportion of approximately 6%. This plan produced the smallest variation in yarn spacing across the reed width.

- Reed Plan No: (95/1.78)

Medium-spacing irregular denting plan. Within each 14-dent section, two dents were left empty, corresponding to an empty-dent proportion of approximately 14%. This plan produced a moderate variation in yarn spacing across the reed width.

- Reed Plan No: (105/1.6)

High-spacing irregular denting plan. Within each 10-dent section, two dents were left empty, corresponding to an empty-dent proportion of approximately 20%. This plan produced the greatest variation in yarn spacing and created distinct intervals in warp-yarn distribution across the reed width.

- Reed Plan No: (172.5/1)

In the plain-weave reference fabric, each warp yarn was dented individually at one end per dent, resulting in a regular reed-denting plan.

The three irregular spacing arrangements presented in Figure 2 enabled a comparative evaluation of the changes in weft crimp, warp crimp, and fabric width associated with differences in reed density.

2.4 Test Methods

Fabric mass per unit area was determined using five 100 cm² specimens taken from different regions of each conditioned fabric sample. Each specimen was weighed using a precision balance, the measured values were converted to g/m², and the arithmetic mean of the five measurements was reported in Table 1. Fabric width measurements of the conditioned fabric samples were carried out in accordance with TS EN 1773:1997, Textiles – Fabrics – Determination of Width and Length [18]. During the measurements, flat and wrinkle-free regions of the fabrics were selected. For each fabric sample, measurements were taken at five different points along the fabric length, and the arithmetic mean of these five measurements was reported. Warp and weft yarn crimp percentages were determined using a James Heal Digital Crimp Tester in accordance with ASTM D 3883–04, Standard Test Method for Yarn Crimp and Yarn Take-up in Woven Fabrics [19]. Fabric specimens measuring 25 cm × 10 cm were prepared from the woven samples. For weft crimp measurements, yarns parallel to the weft direction were examined, while yarns parallel to the warp direction were used for warp crimp measurements. For each fabric sample, ten individual yarn crimp measurements were performed separately in each yarn direction (n = 10 for warp and n = 10 for weft), and the arithmetic mean values were reported.

The experimental data were statistically analyzed using Minitab 22 software. Linear relationships between variables were evaluated using the Pearson correlation coefficient (r), and the significance level was set at $p < 0.05$. Simple linear regression analyses (Fitted Line Plot) were subsequently performed to examine the relationships between fabric width, weft crimp, yarn density, and reed-denting parameters. In addition, three-dimensional scatter plots (3D scatter plots) were used to visualize the spatial distributions of different variable combinations. These plots enabled the simultaneous visualization of patterns associated with weave structure, weft density, and the number of empty reed dents in relation to woven-fabric geometry.

3. RESULTS AND DISCUSSION

3.1 General Findings

In this study, warp crimp, weft crimp, and fabric width were measured for fabrics produced with different weave structures and reed-denting plans. The mean values presented in Table 1 show the variations in yarn-crimp behavior and fabric geometry associated with weave type and reed-denting arrangement.

Overall, an inverse relationship was observed between yarn crimp and fabric width, particularly in relation to weft crimp. An increase in weft crimp was generally accompanied by a reduction in fabric width, whereas increasing the number of empty dents in the reed enlarged the spacing between warp yarns, allowing the weft yarns to be positioned under less lateral constraint. This condition reduced weft crimp and allowed the weft yarns to extend more freely across the fabric width, leading to an increase in fabric width.

When evaluated according to weave type, leno hybrid structures exhibited higher warp crimp because the crossing movement of the warp yarns generated a torsional locking effect. In these structures, the leno warp yarns held the weft yarns more firmly at the interlacement points, thereby restricting their movement and rearrangement within the fabric. This behavior is closely related to the interlacement frequency, float length, and number of yarn transitions within the weave repeat, which govern yarn arrangement and crimp formation in woven structures [11,12]. In contrast, the extended float regions in the straight-float hybrid structures provided greater freedom for weft-yarn movement and redistribution; consequently, these structures generally exhibited higher weft crimp values than the corresponding leno

hybrids. The plain-weave fabric, which contained no intentionally empty reed dents, served as the reference structure because of its regular and balanced interlacement geometry.

Table 1. Structural parameters and measured fabric properties of woven samples produced with different weave architectures and irregular reed denting arrangements.

Weave Type (WVT)	Reed Density (ends/ cm) (RD)	Reed Number	Weft Density (picks/cm) (WD)	Empty Reed Dent Number (EDN)	Reed Dent Spacing (cm/dent)	Total Distance Covered by Weft Crimp in Reed (cm)	Warp Crimp (%) (WAR PC)	Weft Crimp (%) (WC)	Fabric Width (cm) (FW)	Fabric Mass per Unit Area (g/m ²)
3/3 leno hybrid	16.92	90/1.88	17	95	0.111	10.556	7.48	6.7	165.5	109
	16.92	90/1.88	20	95	0.111	10.556	8.4	8.1	166	122
	16.92	90/1.88	23	95	0.111	10.556	8.56	9.2	163	129
3/3 leno hybrid	16.91	95/1.78	17	244	0.105	25.684	7.48	5.9	168	112
	16.91	95/1.78	20	244	0.105	25.684	8.4	6.3	167.5	122
	16.91	95/1.78	23	244	0.105	25.684	8.56	7.6	165.5	130
3/3 leno hybrid	16.80	105/1.6	17	378	0.095	36.000	7.48	5.3	169	109
	16.80	105/1.6	20	378	0.095	36.000	8.4	5.6	168.5	118
	16.80	105/1.6	23	378	0.095	36.000	8.56	6.3	167.5	128
3/3 straight float hybrid	16.92	90/1.88	17	95	0.111	10.556	3.44	7.2	166	110
	16.92	90/1.88	20	95	0.111	10.556	3.55	8.2	164.5	118
	16.92	90/1.88	23	95	0.111	10.556	3.68	8.9	163.5	130
3/3 straight float hybrid	16.91	95/1.78	17	244	0.105	25.684	3.44	6.6	167	109
	16.91	95/1.78	20	244	0.105	25.684	3.55	6.9	166.5	120
	16.91	95/1.78	23	244	0.105	25.684	3.68	7.9	165	129
3/3 straight float hybrid	16.80	105/1.6	17	378	0.095	36.000	3.44	5.6	168.5	108
	16.80	105/1.6	20	378	0.095	36.000	3.55	6.6	167	118
	16.80	105/1.6	23	378	0.095	36.000	3.68	7.2	166	130
5/5 leno hybrid	16.92	90/1.88	17	95	0.111	10.556	5	6.9	166.5	109
	16.92	90/1.88	20	95	0.111	10.556	5.28	8.6	164	120
	16.92	90/1.88	23	95	0.111	10.556	6.8	9.2	163	130
5/5 leno hybrid	16.91	95/1.78	17	244	0.105	25.684	5	6.6	167	110
	16.91	95/1.78	20	244	0.105	25.684	5.28	7.2	166	122
	16.91	95/1.78	23	244	0.105	25.684	6.8	7.6	165.5	130
5/5 leno hybrid	16.80	105/1.6	17	378	0.095	36.000	5	5.6	168.5	109
	16.80	105/1.6	20	378	0.095	36.000	5.28	5.9	168	118
	16.80	105/1.6	23	378	0.095	36.000	6.8	6.3	167.5	128
5/5 straight float hybrid	16.92	90/1.88	17	95	0.111	10.556	3.24	7.2	166	109
	16.92	90/1.88	20	95	0.111	10.556	3.52	8.6	164	120
	16.92	90/1.88	23	95	0.111	10.556	3.68	8.6	164	130
5/5 straight float hybrid	16.91	95/1.78	17	244	0.105	25.684	3.24	6.6	167	109
	16.91	95/1.78	20	244	0.105	25.684	3.52	7.2	166	120
	16.91	95/1.78	23	244	0.105	25.684	3.68	7.6	165	130
5/5 straight float hybrid	16.80	105/1.6	17	378	0.095	36.000	3.24	5.6	168.5	107
	16.80	105/1.6	20	378	0.095	36.000	3.52	6.3	167.5	119
	16.80	105/1.6	23	378	0.095	36.000	3.68	6.9	166.5	128
1/1 Plain Weave	17.25	172.5/1	17	0	0.058	0.000	3.64	6.3	167.4	109
	17.25	172.5/1	20	0	0.058	0.000	5	7.5	165.6	117
	17.25	172.5/1	23	0	0.058	0.000	6.75	8.3	164.4	128

Note: The reported fabric width and fabric mass per unit area values represent arithmetic means obtained from five measurements for each fabric sample (n = 5). Fabric width was measured at five different points along the fabric length, while fabric mass per unit area was determined using five specimens taken from different regions of each fabric sample. Warp and weft crimp values represent the arithmetic means of ten individual yarn measurements performed separately in each yarn direction (n = 10 for warp and n = 10 for weft). As only the mean values were available in the archived dataset, within-sample standard deviations and confidence intervals could not be reconstructed retrospectively.

3.2 Correlation Analysis

The results of the Pearson correlation analysis conducted to investigate the relationships among different weaving parameters are presented in Figure 3. The analysis revealed several statistically significant relationships among fabric width, yarn crimp behavior, and reed parameters ($p < 0.05$).

Overall, a strong negative correlation was found between fabric width (FW) and weft crimp (WC) ($r = -0.981$, $p = 0.000$). This result indicates that higher WC values were associated with lower FW values. Greater crimp formation in the weft yarns was associated with lateral contraction of the fabric structure and a corresponding reduction in effective fabric width. This relationship is consistent with established woven-fabric geometry, according to which changes in yarn path and crimp influence the dimensions of the fabric structure [4,11,13]. Similarly, FW exhibited a moderate negative correlation with weft density (WD) ($r = -0.559$, $p = 0.000$). Increasing WD resulted in closer yarn packing within the fabric structure, which was accompanied by increased WC and reduced FW. Similar effects of yarn density on yarn crimp and woven-fabric geometry have also been reported in previous studies [10,15].

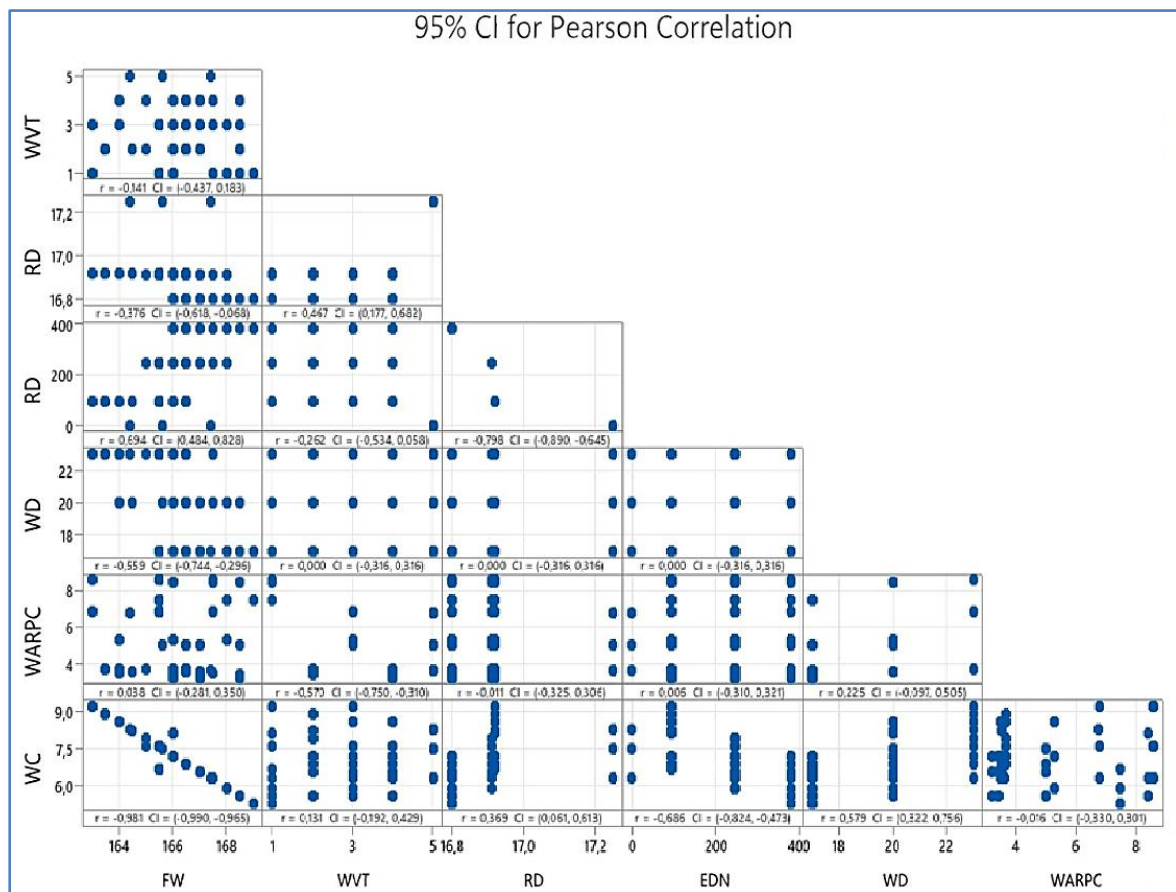


Figure 3. Pearson correlation coefficients among weaving parameters (r : correlation coefficient; $p < 0.05$ was considered statistically significant).

In contrast, the number of empty reed dents (EDN) showed a positive correlation with FW ($r = 0.694$, $p = 0.000$). The empty spaces created by intentionally leaving reed dents unoccupied enabled the weft yarns in these regions to follow a straighter path with reduced crimp formation. The reduction in crimp allowed the weft yarns to extend more freely across the fabric width, which was associated with higher FW values. Accordingly, increasing EDN tended to be associated with wider fabrics. The negative correlation between reed density (RD) and FW ($r = -0.376$, $p = 0.018$) further indicated that denser reed structures were associated with more closely positioned yarns and reduced fabric width.

From the perspective of crimp behavior, no statistically significant linear relationship was observed between WC and warp crimp (WarpC) ($r = -0.016$, $p = 0.924$). This finding indicates that no consistent linear association between warp and weft crimp was detected across the investigated fabric constructions. The two yarn systems may have responded differently to the tension, interlacement, and yarn-positioning conditions generated by the different weave structures and reed denting arrangements. These correlations demonstrate the general tendencies among the variables. The identified relationships were further examined using simple regression analyses and three-dimensional scatter plots to evaluate the combined patterns involving weave structure, weft density, irregular reed denting, fabric width, and yarn crimp behavior.

3.3 Simple Regression Analysis

Simple linear regression analyses were performed for pairs of continuous variables that showed statistically significant correlations ($p < 0.05$). The resulting regression equations, coefficients of determination (R^2), and significance levels (p) are summarized in Table 2.

The regression models presented in Table 2 quantified the relationships of weft density (WD), weft crimp (WC), reed density (RD), and empty reed dent number (EDN) with fabric width and weft crimp. Particularly, EDN was positively associated with fabric width and negatively associated with weft crimp, quantitatively demonstrating the role of irregular reed-denting arrangements in woven-fabric geometry. Although reed density and reed count have been discussed in the weaving literature, quantitative investigations of intentionally created empty dents distributed across different reed regions remain limited. By quantifying the relationships of EDN with fabric width and weft crimp, the present study contributes to the limited body of research on irregular reed-denting arrangements.

Table 2. Simple linear regression models and coefficients of determination (R^2) for the parameters associated with fabric width and weft crimp.

Dependent Variable	Independent Variable	Regression Equation	R^2 (%)	p	Effect Direction
Fabric Width (FW)	Weft Density (WD)	$FW = 173.5 - 0.3654 \text{ WD}$	31,3	0,000	Negative
Fabric Width (FW)	Weft Crimp (WC)	$FW = 176.7 - 1.484 \text{ WC}$	96,3	0,000	Strong Negative
Fabric Width (FW)	Number of Empty Reed Dents (EDN)	$FW = 164.3 + 0.008669 \text{ EDN}$	48,1	0,000	Positive
Weft Crimp (WC)	Weft Density (WD)	$WC = 2.095 + 0.2500 \text{ WD}$	33,5	0,000	Positive
Weft Crimp (WC)	Reed Density (RD)	$WC = -51.72 + 3.479 \text{ RD}$	13,7	0,021	Positive
Weft Crimp (WC)	Number of Empty Reed Dents (EDN)	$WC = 8.346 - 0.005673 \text{ EDN}$	47,1	0,000	Negative

The regression results showed that EDN was positively associated with FW ($R^2 = 48.1\%$), indicating that higher EDN values were associated with wider fabrics. Increasing EDN created larger local gaps between groups of warp yarns, thereby reducing the lateral constraint on weft-yarn positioning and allowing the weft yarns to extend more freely across the fabric width. Although reed count and density have been discussed in the weaving literature, quantitative investigations of regionally distributed empty dents remain limited. Therefore, quantifying the gradual relationship between EDN and FW constitutes an important technical contribution of the present study.

EDN was negatively associated with WC, with the model explaining 47.1% of the variation in WC. Crimp distribution across the fabric width is closely related to yarn arrangement and fabric-setting parameters [7]. In the investigated fabrics, the irregular lateral spacing created by the empty reed dents altered the positioning of the weft yarns and allowed them to follow a less undulated path. This tendency was particularly evident in the hybrid structures and was reflected in their measured weft crimp values.

Because weave type is a categorical variable, the WarpC, WC, and fabric-width patterns of the five weave categories were examined using three-dimensional scatter plots rather than simple linear regression. The graphical comparisons showed that the leno hybrid structures generally exhibited higher WarpC values, whereas the straight-float hybrid structures tended to exhibit higher or comparable WC values. The plain-weave fabric was included as the reference structure. The scatter plots therefore displayed the observed differences among the investigated weave categories without imposing a linear or ordinal relationship among their numerical codes.

Overall, this study contributes to the quantitative investigation of irregular reed denting by examining different empty-dent distributions and quantifying their relationships with fabric width and weft crimp. Three-dimensional scatter plots additionally displayed the patterns associated with weave architecture, irregular reed denting, and weft

density. Thus, Table 2 provides quantitative relationships among the continuous variables, while the graphical analyses facilitate comparisons among the investigated weave categories and provide a broader understanding of irregular reed denting in relation to woven-fabric geometry.

3.4 Scatter Plot Analysis by Weave Type

Three-dimensional scatter plots were used to examine the variations in warp crimp (WarpC), weft crimp (WC), and fabric width (FW) across the investigated weft density (WD) and empty reed dent number (EDN) levels for each weave structure. The spatial distribution of the measured values provided a comparative representation of the changes in yarn crimp and fabric width associated with the different combinations of weave architecture, WD, and EDN.

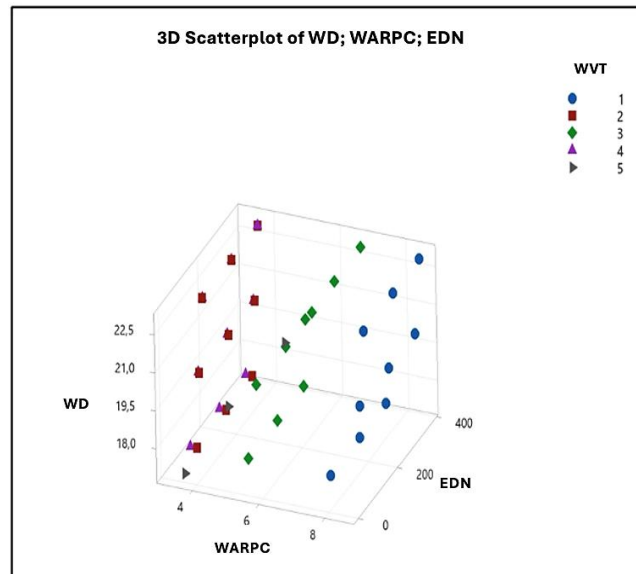


Figure 4. Three-dimensional scatter plot of weft density (WD), empty reed dent number (EDN), and warp crimp (WarpC), grouped by weave type.

The three-dimensional distribution presented in Figure 4 illustrates the variation in warp crimp (WarpC) across the investigated weave types, weft density (WD) levels, and empty reed dent number (EDN) levels. The leno hybrid structures (Weave Codes 1 and 3) generally exhibited higher WarpC values than the straight-float hybrid structures (Codes 2 and 4), owing to the torsional locking effect generated by the crossing movement of the warp yarns. Higher WD was also associated with higher WarpC values because closer yarn packing and increased interlacement frequency required greater warp-yarn undulation [10]. However, within each weave structure and WD level, WarpC remained unchanged across the different EDN levels. Thus, WarpC varied primarily with weave architecture and WD rather than with EDN. The plain-weave fabric (Code 5), which contained no intentionally empty reed dents, was plotted at EDN = 0 as the reference structure.

The three-dimensional scatter plot presented in Figure 5 illustrates the variation in weft crimp (WC) across the investigated weave types, weft density (WD) levels, and empty reed dent number (EDN) levels. In the present dataset, WC increased with increasing WD across all investigated weave structures. In contrast, WC generally decreased as EDN increased, indicating that the additional spacing created by the empty reed dents allowed the weft yarns to follow a less undulated path within the fabric structure. When the corresponding hybrid structures were compared, the straight-float hybrids (Weave Codes 2 and 4) generally exhibited WC values that were slightly higher than or comparable to those of the leno hybrids (Codes 1 and 3). This tendency may be attributed to the greater freedom of movement and redistribution afforded to the weft yarns by the extended float regions, whereas the torsional locking effect in the leno structures restricted their rearrangement. The plain-weave fabric (Code 5), which contained no intentionally empty reed dents, was plotted at EDN = 0 and served as the reference structure.

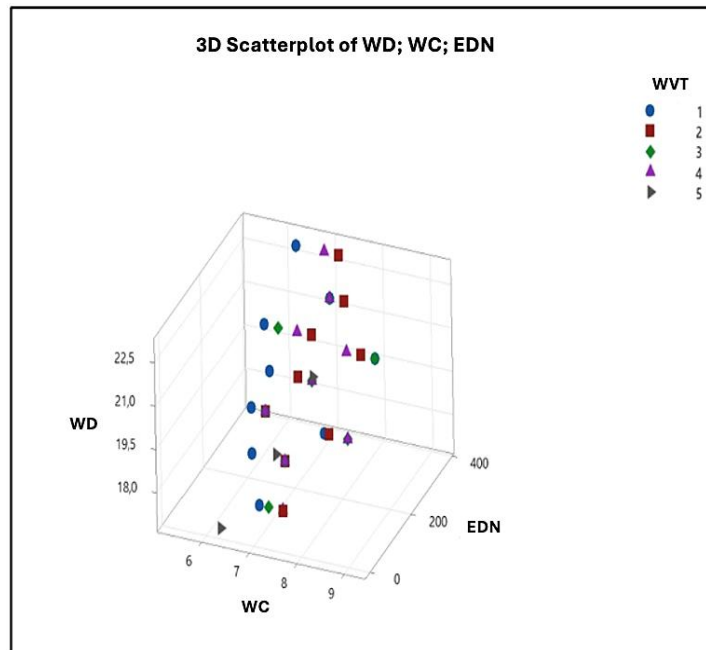


Figure 5. Three-dimensional scatter plot of weft density (WD), empty reed dent number (EDN), and weft crimp (WC), grouped by weave type.

Figure 6 illustrates the variation in fabric width (FW) across the investigated weave types, empty reed dent number (EDN) levels, and weft density (WD) levels. Across the investigated hybrid structures, FW generally increased as EDN increased. The additional spacing created by intentionally leaving reed dents empty reduced the lateral constraint on weft-yarn positioning and allowed the weft yarns to extend more freely across the fabric width. This tendency was observed in both the leno and straight-float hybrid structures, although the width values differed among the weave architectures. The plain-weave fabric (Code 5), which contained no intentionally empty reed dents, was plotted at $EDN = 0$ and served as the reference structure.

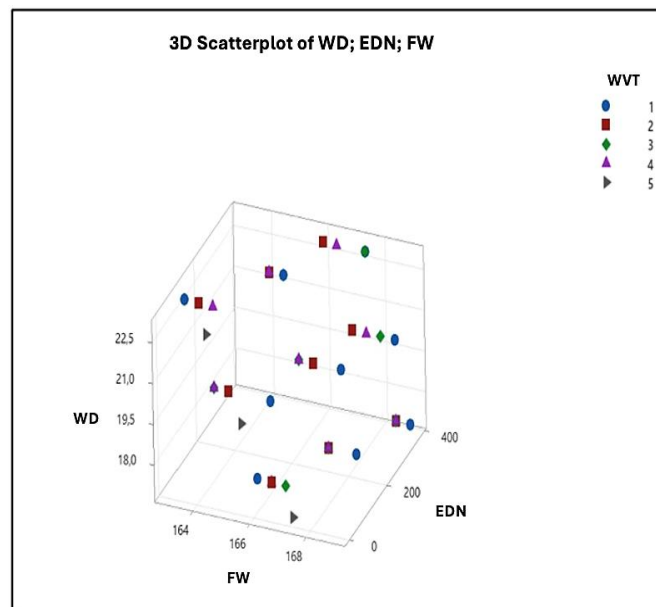


Figure 6. Three-dimensional scatter plot showing the relationship among weft density (WD), empty reed dent number (EDN), and fabric width (FW), grouped by weave type.

Increasing WD was generally associated with a reduction in FW across the investigated weave structures. The closer packing of weft yarns at higher WD levels increased the structural compactness of the fabrics and was accompanied by higher WC values, thereby contributing to lateral fabric contraction. The three-dimensional distribution therefore visualizes the joint patterns of weave type, EDN, and WD in relation to FW. However, because a formal statistical interaction analysis was not performed, the plot should be interpreted as a graphical representation of the combined distribution of these variables rather than as statistical evidence of interaction effects.

4. CONCLUSION

This study provides an experimental and statistical evaluation of the effects of irregular reed denting arrangements on fabric width (FW), warp crimp (WarpC), and weft crimp (WC) in woven fabrics. The results showed that increasing the number of empty reed dents generally increased FW and reduced WC across the investigated hybrid structures. In contrast, WarpC remained unchanged across the EDN levels within each weave structure and weft density, indicating that its variation was primarily associated with weave architecture and WD. Leno hybrid structures exhibited higher WarpC values because of the torsional locking effect generated by the crossing warp yarns, whereas the extended float regions in the straight-float hybrid structures allowed greater movement and redistribution of the weft yarns and generally produced higher or comparable WC values. The plain-weave fabric, which contained no intentionally empty reed dents, served as the reference structure for evaluating these variations.

The combined patterns observed in the statistical analyses and three-dimensional scatter plots indicated that the effects of EDN on fabric width and yarn crimp should be evaluated together with weave architecture and weft density. From a practical perspective, irregular reed denting can be considered a fabric-design parameter for adjusting lateral yarn spacing and obtaining the desired fabric width and crimp characteristics. However, the denting plan should be selected according to the weave structure and weft density, since the same empty-dent arrangement may produce different responses in different fabric constructions. These findings can assist weaving manufacturers and fabric designers in determining suitable reed-denting arrangements during fabric development and reducing the number of trial adjustments required to achieve the targeted fabric geometry. Future studies should extend the experimental design to different yarn counts, twist factors, fiber types—including polyester, viscose, and elastane—and weave structures. The effects of production conditions such as warp tension, loom speed, and finishing processes should also be investigated to determine whether the observed relationships remain consistent under different industrial conditions.

Authors' Contributions

No	Full Name	ORCID ID	Author's Contribution
1	Bilge Berkhan Kastacı	0000-0001-6897-0554	1, 2, 3, 4, 5
1- Study design 2- Data collection 3- Data analysis and interpretation 4- Manuscript writing 5- Critical revision			

Funding

This research received no external funding.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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