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Predicting the Stitch Density of Finished Fabrics Using Weft Blended Grey Knit Fabrics

Kazi Md. Elias[1*], Mohammad Obaidur Rahman[1], H. M. Zakir Hossain[2]

[1]Department of Physics, Jahangirnagar University, Savar, Bangladesh
[2]Jute Textile Wing, Bangladesh Jute Research Institute, Dhaka, Bangladesh
Email: *kazi-elias@ttsl-bd.com

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Abstract

Stitch density is one of the critical quality parameters of knit fabrics. This parameter is closely related to other physical quality parameters like fabric weight, fabric tightness factor, fiber types, blend ratio, yarn diameter and linear density, and fabric structure. Selecting stitch density (wales per inch, course per inch) is essential to getting the appropriate fabric weight and desired quality. Usually, no rules or assumptions exist to get the desired stitch density in the finished fabric stage. Fifteen types of blended knit fabrics were prepared to conduct the study. The varying percentages of cotton, polyester, and elastane are incorporated in the blends. Regression analysis and regression ANOVA tests were done to predict the stitch density of finished fabrics. A suitable regression equation is established to get the desired results. The study also found that the stitch density value in the finished stage fabric decreases by approximately 15% compared to the stitch density in the grey fabric stage. This study will help the fabric manufacturers get the finished fabric stitch density in advance by utilizing the grey fabric stitch density data set. The author expects this research to benefit the knitting and dyeing industry, new researchers, and advanced researchers.

Keywords

Wales per Inch, Course per Inch, Stitch Density, Blended, Knit, Fabric

1. Introduction

1.1. Background of the Research

The study focused on predicting the stitch density of weft-knitted blended fabrics. The textile manufacturing industry produces fabrics with the required fabric count or fabric density. The fabric density is the product of ends per inch and picks per inch in woven fabric. This same parameter is known as stitch density in knit fabrics. The stitch density is the product of wales per inch and picks per inch. The recent trend of fabric manufacturers is to check the stitch density once the fabric is finished. Considering their personal experiences, they assume and expect to get the desired result (stitch density). This study utilized grey fabrics to check the stitch density in the grey fabric stage. The regression model was developed to predict the stitch density parameters of finished fabrics using the grey fabric stitch density parameters. This is a helpful study of the textile industry's production, quality control, and R&D divisions.

1.2. Literature Survey

An experiment conducted by some researchers on the stitch density affecting the garment seam strength. Their findings helped design and decide the desired seam strength behavior, and the regression equation was also developed to predict seam strength in advance. However, the experiment was only for ready-made woven garments [1]. One study revealed stitch density and length's noticeable effects on the dimensional stability and bursting strength test value [2]. Bin SZ. & *et al.* investigated the effect of the knitted structure and yarn count on the fabric properties. The wales per inch and course per is a factor affecting fabric properties [3]. Reazuddin Repon *et al.*, in their research, showed the relationship among wales per inch, course per inch, yarn count, dyeing, and finishing performance [4]. Riasat Alam AM *et al.* also investigated the relationship between different physical properties such as stitch length, density, fabric weight, dimensional stability, tightness factor, etc. [5]. So far, the literature survey found that many researchers who studied stitch density or fabric count in weft-knitted fabrics have not developed any predictable model or regression equation. This study is new and original research. The study findings are helpful to the fabric manufacturers and buyers who decide and set the stitch density parameters.

1.3. What Is Stitch Density?

Wales per inch (WPI) is the column of loops running lengthwise to the fabric known as wale. Course per Inch (CPI) is the horizontal row of loops or stitches running across the width of the knitted fabric. Stitch density can be obtained by multiplying the Wales per unit length and the course per unit length. **Figure 1** shows the position of wales and course in the knit fabric structure.

1.4. Factors Responsible for Stitch Density

1.4.1. Yarn Stage

Stitch density is affected by yarn's physical and chemical properties. The higher the yarn diameter, the higher the stitch density. The higher the yarn linear density, the higher the stitch density. The linear density of the yarn influences the fabric property [6] [7]. The higher the twist per inch, the higher the stitch density. The higher the yarn crimp percentage, the higher the stitch density. The structure of yarn also influences stitch density. The tight structure tends to have higher stitch density and vice versa. Stitch density and lycra content can change the physical properties of yarn and fabric [8].

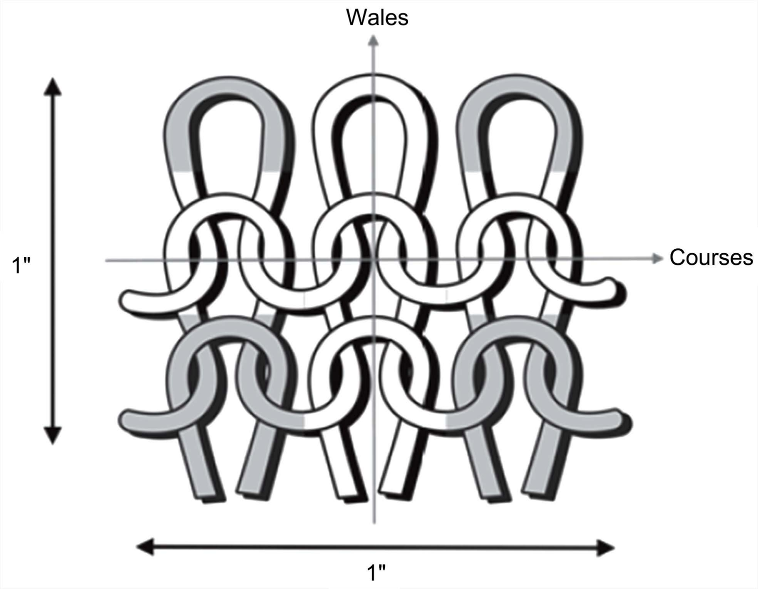

Figure 1. Position of Wales and course.

1.4.2. Knitting

The loop length, stitch length, inlay tension in knitting, machine dia, number of feeders, knitting machine gauge, etc., affect the wales per inch, course per inch, and ultimately, stitch density. The influences of the loop length and the raw material on the number of courses per unit length and the number of wales per unit length affect stitch density [9].

1.4.3. Fabric Stage

Fabric properties influence stitch density. The fabric properties include fabric weight (GSM), fabric cover factor, fabric tightness factor, fabric structure, fabric porosity, fabric thickness, fabric design, fabric air permeability, fabric tensile strength, bursting strength, fabric tear strength, fabric shear property, fabric dimensional stability, fabric spirality or twisting, etc. The higher the spirality, the lower the stitch density. The stitch density plays a vital role in seam comfort properties [10]. Usually, the fabric with higher stitch density tends to have higher tensile, bursting, and tear strength. Stitch density affects the dimensional property of knit fabric [11]. The fabric with higher air permeability provides a lower stitch density. The fabric or garment comfort also depends on fabric density or stitch density [12]. The mechanical rupture of fabric is affected by stitch density [13]. Stitch density can affect garment seam quality [14].

1.4.4. Dyeing & Finishing Stage

The steering and compacting of fabric tend to increase or decrease fabric weight (GSM) and, accordingly, the wales per inch, course per inch, *i.e.*, the stitch density changes [15]. The steering and compacting of fabric tend to increase or decrease fabric weight (GSM) and, accordingly, the wales per inch, course per inch, *i.e.*, the stitch density changes. Stitch length and density affect the finished fabric drape behavior [16]. Stitch density is also responsible for better sensational comfort in finished fabric [17].

1.4.5. Testing Stage

In the testing stage, the stitch density result may vary based on the accuracy and precision of testing. The reliability and acceptability of the test results mainly depend on the 3M (Man, Machine, and Material), such as the technician's skills, depth of knowledge of the test procedure, ability to analyze test results, use of appropriate equipment and accessories using calibrated measuring devices, maintaining repeatability tests, re-checking, retesting, duplicate testing, or related in-house quality control activities.

2. Materials & Methods

2.1. Blended Fabrics

The study used single jersey weft blended knitted fabrics with three different textile fibers: cotton, polyester, and elastane, with varying percentages of blend proportions. The yarn count and fabric weight were 34/1 ring-spun and 180 GSM (Gram per square meter). Table 1 shows the names of fifteen blended fabrics used in this study.

Table 1. Types of blended knit fabrics.

SN.	Fabric Type	Fabric Composition
1	CVC, Single Jersey Lycra Fabric	Cotton 90%, Polyester 5%, Elastane, 5%
2	CVC, Single Jersey Lycra Fabric	Cotton 90%, Polyester 6%, Elastane, 4%
3	CVC, Single Jersey Lycra Fabric	Cotton 90%, Polyester 7%, Elastane, 3%
4	CVC, Single Jersey Lycra Fabric	Cotton 90%, Polyester 8%, Elastane, 2%
5	CVC, Single Jersey Lycra Fabric	Cotton 90%, Polyester 9%, Elastane, 1%
6	CVC, Single Jersey Lycra Fabric	Cotton 85%, Polyester 10%, Elastane, 5%
7	CVC, Single Jersey Lycra Fabric	Cotton 85%, Polyester 11%, Elastane, 4%
8	CVC, Single Jersey Lycra Fabric	Cotton 85%, Polyester 12%, Elastane, 3%
9	CVC, Single Jersey Lycra Fabric	Cotton 85%, Polyester 13%, Elastane, 2%
10	CVC, Single Jersey Lycra Fabric	Cotton 85%, Polyester 14%, Elastane, 1%
11	CVC, Single Jersey Lycra Fabric	Cotton 80%, Polyester 15%, Elastane, 5%
12	CVC, Single Jersey Lycra Fabric	Cotton 80%, Polyester 16%, Elastane, 4%
13	CVC, Single Jersey Lycra Fabric	Cotton 80%, Polyester 17%, Elastane, 3%
14 15	CVC, Single Jersey Lycra Fabric	Cotton 80%, Polyester 18%, Elastane, 2%
15	CVC, Single Jersey Lycra Fabric	Cotton 80%, Polyester 19%, Elastane, 1%

Note. CVC stands for Chief Value Cotton.

Preparatory Process Involved in the Study

The cotton used in production is imported from the US, along with elastane and staple polyester. The raw cotton was examined for various parameters, including strength, elongation percentage, Rd (71.0), +b (9.8), maturity index, uniformity ratio index, spinning consistency index (138), upland grading (42-1), short fiber content (243), and rubbish grade. High-quality spinning equipment created a superior yarn with a count of 34/1 Ne ring-spun. The grey textiles were produced using the latest knitting machines from Terrot, Germany. The machines had a 32-inch diameter, a 24-gauge machine, a 29.0 mm stitch length, a yarn linear density of 34/1 Ne, a grey GSM of 180, and a completed GSM of 180. BEZEMA, a German company, produces premium dispersion dyes and brand-appropriate auxiliaries. Reactive and dispersion dyes were used to dye the blended fabrics. Stenter (Monfortis, Germany) and Compactor (Lafer, Italy) equipment were used to process the fabrics and produce the final prototypes.

2.2. Methods

2.2.1. Test Standard

The international test standard BS 5441-2019 [18] uses test methods for knitted fabrics to measure stitch density.

2.2.2. Test Equipment & Apparatus

The stitch density test used the Pick Glass, counting needle, and digital calculator. **Figure 2** shows a pick glass and counting needle, and **Figure 3** shows the measurement of fabric count.

2.2.3. Test Procedure

The specimen was kept in a conditioning environment following the (65% RH ± 4% RH and 20˚C ± 2˚C). ISO 139 [19]. A pick counter (manual) and counting needle determine the number of wales/inch and course per inch. Five readings were taken from each type of fabric, and the average readings were calculated. The calculation was based on the formula: Stitch Density = Wales per inch X Course per inch.

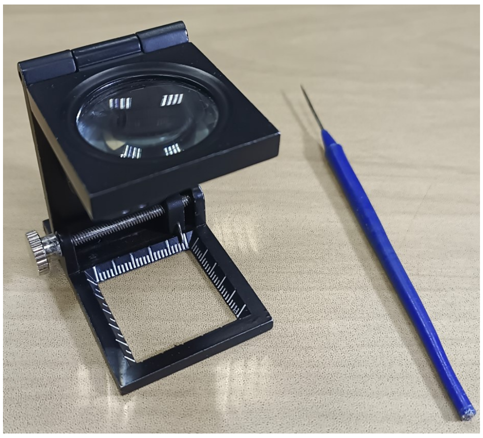

Figure 2. Pick counter and needle.

Figure 3. Measuring fabric count.

2.2.4. Calculation of the Test Result

The stitch density can be calculated by using the formula:

Say, W = number of wales per unit length

Say, C = number of courses per unit length

Stitch Density = W × C

The wales or course unit length may be an inch, centimeter, or millimeter.

3. Result and Discussion

3.1. Graphical Representation of Stitch Density Data of Grey Fabrics

Figure 4 represents the graphical representation of the stitch density of grey fabrics. The x-axis indicates the types of blended knit fabrics, and the y-axis indicates the stitch density of the grey fabric data set. The error bar is incorporated into the graph to visualize the variation of stitch density.

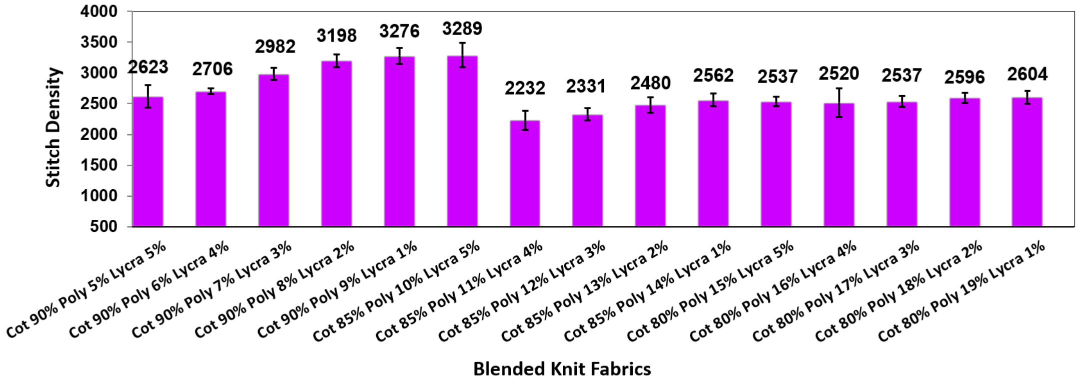

Figure 4. A graphical display of the stitch density of grey blended fabrics.

3.2. Graphical Representation of Stitch Density Data of Finished Fabrics

Figure 5 represents the graphical representation of the stitch density of finished fabrics. The x-axis indicates the types of blended knit fabrics, and the y-axis indicates the stitch density of the finished grey fabric data set. The error bar is incorporated into the graph to visualize the variation of stitch density.

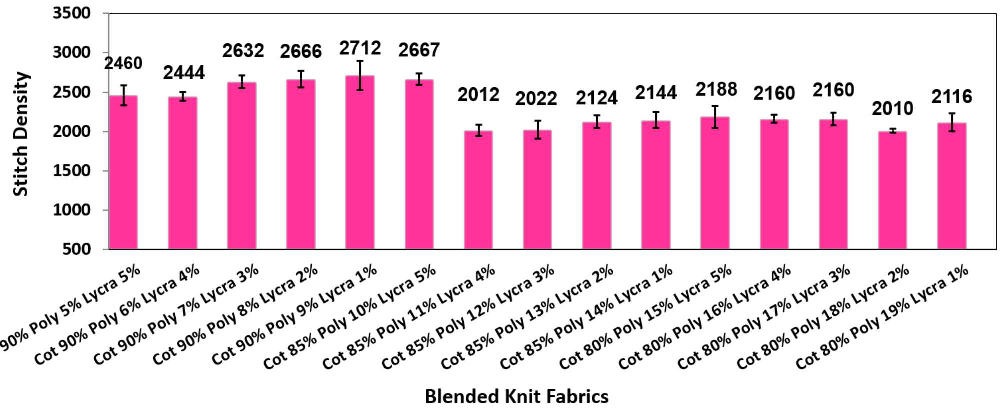

Figure 5. A graphical display of the stitch density of finished blended fabrics.

3.3. Comparative Data Analysis of Stitch Density for Grey and Finished Fabric

Table 2 shows the comparative data for grey and finished fabrics. **Figure 6** represents a comparative study of stitch density between grey and finished fabrics. The x-axis indicates the types of blended fabrics, and the y-axis indicates the stitch density of grey and finished fabrics.

Table 2. Comparative data of stitch density – Grey and Finished fabric.

Serial No	Type of Fabric	Stitch Density Grey Fabric	Stitch Density Finished Fabric
1	90% Cotton, 5% Polyester, 5% Elastane	2623	2460
2	90% Cotton, 6% Polyester 4% Elastane	2706	2444
3	90% Cotton, 7% Polyester 3% Elastane	2982	2632
4	90% Cotton, 8% Polyester, 2% Elastane	3198	2666
5	90% Cotton, 9% Polyester, 1% Elastane	3276	2712
6	85% Cotton, 10% Polyester 5% Elastane	3289	2667
7	85% Cotton, 11% Polyester 4% Elastane	2232	2012
8	85% Cotton 12% Polyester 3% Elastane	2331	2022
9	85% Cotton, 13% Polyester, 2% Elastane	2480	2124
10	85% Cotton, 14% Polyester, 1% Elastane	2562	2144
11	80% Cotton, 15% Polyester 5% Elastane	2537	2188
12	80% Cotton 16% Polyester 4% Elastane	2520	2160
13	80% Cotton, 17% Polyester, 3% Elastane	2537	2160
14	80% Cotton, 18% Polyester, 2% Elastane	2596	2010
15	80% Cotton, 19% Polyester, 1% Elastane	2604	2116

From the comparative data set obtained from Table 2, the data trend shows that the stitch density of the finished fabric decreased significantly compared to the stitch density of grey fabrics, approximately 15%. This finding is also helpful for the fabric manufacturer in deciding the expected stitch density in finished fabric cost in advance. Figure 6 shows the graphical representation of the grey and finished stage fabric's stitch density value.

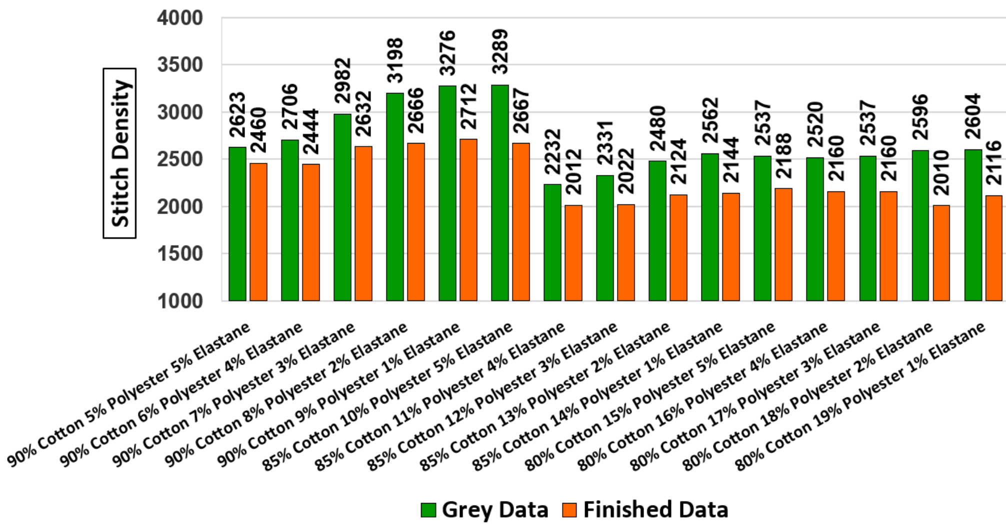

Figure 6. A graphical display of the stitch density of grey and finished fabrics.

3.4. Effect of Cotton Blend Ratio on Stitch Density

Cotton is soft fiber. A single jersey made from 100% cotton is a standard fabric. The fabric becomes softer once the cotton is blended with polyester and elastane, providing a better and expected fabric count or stitch density. The addition of polyester and elastane in the blend improves the knit fabric's stretchability. The gradual decrease of cotton fiber in the blend tends to lower stitch density and vice versa. The gradual increase of polyester fiber percentage tends to lower stitch density. The gradual decrease of elastane fiber does not affect the stitch density but gives good comfort and a smooth fabric surface.

3.5. Statistical Analysis

3.5.1. Regression Analysis

The statistical analysis was done through regression analysis. The R^2 was found to be 0.8452, meaning that the grey fabric stitch density explains 84.52% of the variability. The regression equation obtained was **Y = 0.7334 X + 322.3261.** The regression equation shows that with one increase in grey fabric stitch density, the value of finished fabric stitch density increases by 0.7334. The y-intercept is 322.3261, meaning that when x (grey fabric stitch density) equals 0, the finished fabric stitch density prediction is 322.3261. Figure 7 shows the regression graph from grey and finished fabric stitch density data.

1) Reliability Check of R^2

- The adjusted R_{adj}^2 (Adjusted R-squared) was calculated using the formula for assessing the R^2

$$R_{adj}^2 = 1 - \frac{(1-R^2)(n-1)}{n-p-1} = 0.8294 \sim 0.82$$

where, R^2 = R – Squared

n = Number of samples

p = Number of predictors

The adjusted R_{adj}^2 indicated that the independent variable (Grey fabric stitch density) adds value to the regression model.

- The Shapiro-Wilk test p-value was 0.4503, indicating that the data are normally distributed.
- The study data does not contain any outlier data.

Considering the actual facts, the regression predictive equation or model is considered the line of best fit.

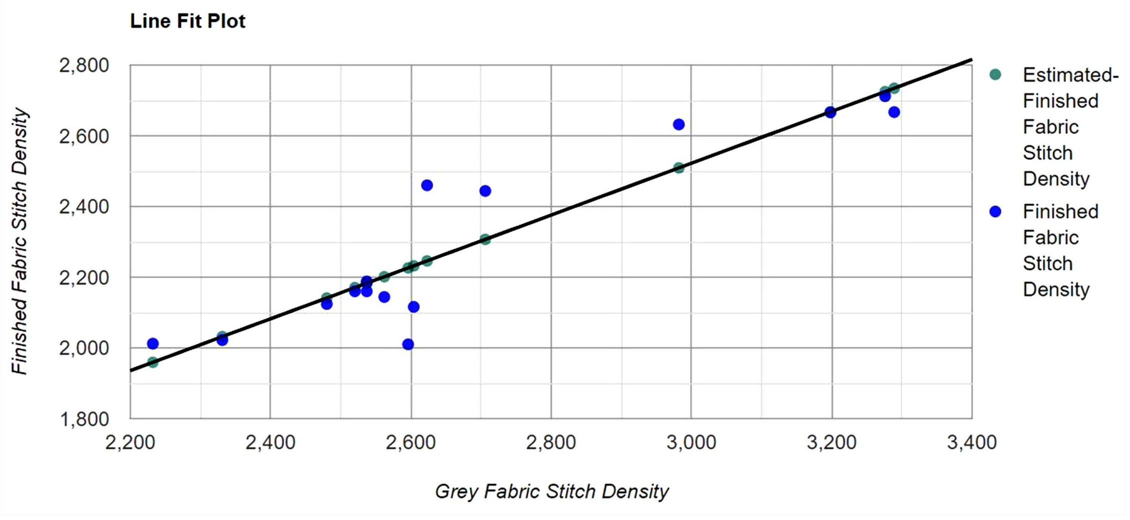

Figure 7. Regression graph for grey and finished fabrics.

3.5.2. Interpretation of Regression Analysis

An explanation and calculation were given to predict the finished fabric stitch density from the grey fabric's density value. For example, If the grey fabric stitch density is 2500, 2800, and 3000, we can predict the finished fabric stitch density as 2155.7773, 2375.7915, and 2522.4676, respectively, where the prediction interval is (1911.8854, 2399.6692), (2134.005, 2617.578), and 2272.8493, 2770.0858). Figure 8 shows a regression graph with the predicted stitch density of finished fabrics.

The textile community, including the textile manufacturing unit, research organization, and sustainability development team, can assess and decide the desired stitch density of finished-stage knit fabric using the grey-stage knit fabric dataset, especially the blended fabric because the research was conducted with blended knit fabrics.

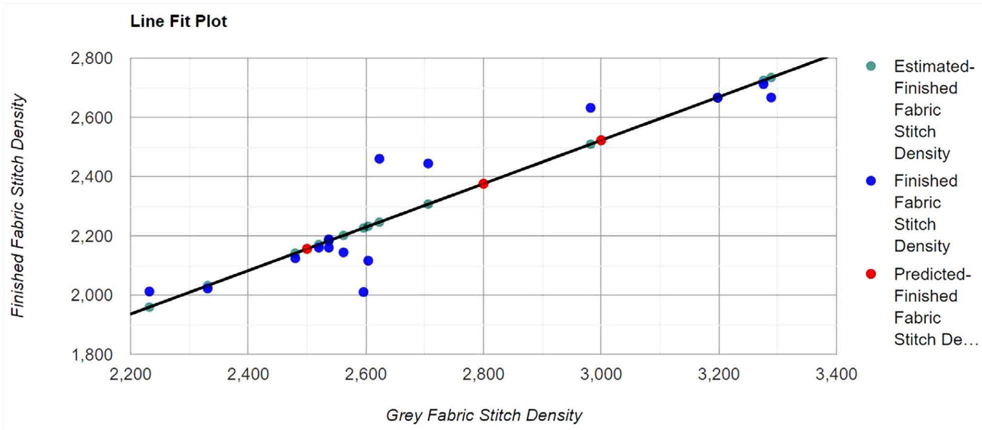

Figure 8. Regression graph with predicted stitch density finished fabrics.

3.5.2. Regression Analysis through ANOVA

A regression analysis with ANOVA was also performed to check the statistical significance. A hypothesis statement was prepared before the ANOVA (analysis of variance).

H0: There is no relationship between the dependent variable (finished fabric stitch density) and independent variables (grey fabric stitch density).

Ha: There is a relationship between the dependent variable (finished fabric stitch density) and independent variables (grey fabric stitch density).

Table 3 shows the regression ANOVA table for grey and finished fabrics.

Table 3. Regression for ANOVA.

Source	*df*	*SS*	*MS*	*F*	*P value*
Regression	1	828467.3794	828467.3794	70.9948	0.000001262
Residual	13	151702.3539	11669.4118		
Total	14	980169.7333	70012.1238		

The correlation coefficient (R) and the coefficient of determination (R^2) were found to be 0.9194 and 0.8452, respectively. It indicates a strong direct relationship between grey fabric and the finished stitch density data set. From the Table 3, it was observed that the p-value (0.000001261) < α (0.05). Then, the null hypothesis was rejected. A 95% confidence interval or 5% significance level is chosen for the study. The analysis shows that the regression ANOVA is significant, meaning that the regression equation for finished fabric, Y = 0.7334*X + 322.3261, is statistically significant. Table 4 shows the example predicted data.

Table 4. Predicted example data.

Grey Fabric SD	*Finished Fabric SD Prediction*	*Confidence Interval*	*S.E. Confidence Interval*	*Prediction Interval*	*S.E. Prediction Interval*
2500	2155.7773	2084.9263, 2226.6284	32.7958	1911.8854, 2399.6692	112.8937
2800	2375.7915	2312.5671, 2439.0158	29.2655	2134.005, 2617.578	111.9191
3000	2522.4676	2439.6943, 2605.2408	38.3144	2274.8493, 2770.0858	114.6185

Note. *SD stands for Stitch Density, and S.E. stands for Standard Error.*

4. Conclusion

The density of stitches in a fabric is directly linked to the fabric weight, measured in GSM (grams per square meter). A higher stitch density results in a higher fabric weight. It is crucial to control the stitch density in fabric as it impacts various physical test parameters such as bursting strength, tensile strength, tearing strength, fabric handle, drape, and stiffness. After conducting experiments and statistical significance tests, the study concluded that a regression model could predict the stitch density of weft-knitted finished fabrics, allowing textile industry professionals to foresee the stitch density in the grey and finished fabric stages. The study also found that the stitch density of the finished fabric decreased by approximately 15% compared to the grey fabric stage. Additionally, the blend proportions of polyester fibers changed between the grey and finished fabric stages. The study focused on fabrics made of three different fibers—cotton, polyester, and spandex—each with varying blend ratios. Moving forward, the research aims to explore recycled and virgin fibers with diverse blend proportions to promote sustainable development in the textile industry. There is potential for further exploration into the stitch density of woven fabrics, considering different fabric structures and fibers with varying blend proportions.

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Conflicts of Interest

The authors declare no conflict of interest in this research work.

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