

SIZING EFFICIENCY AND COST REDUCTION STRATEGIES IN WOVEN FABRIC MANUFACTURING: A CASE STUDY

Abdullah Al Rakib Shikder¹
Rijon Saha
Tarikul Islam
Jabed Hossen Emon
Md. Humayun Kabir Khan

Received 08.01.2024.
Revised 21.02.2024.
Accepted 18.03.2024.

Keywords:

Sizing, optimization, cost-effective, weaving efficiency, ANOVA analysis.

Original research



ABSTRACT

This study aims to optimize the cost of woven fabric production by investigating critical factors, with a specific focus on sizing and weaving efficiency. The study identifies an optimal sizing process to reduce costs while maintaining yarn properties. Two yarn counts, 45Ne(13Tex) and 30Ne(20Tex), were tested with four sizing baths, revealing that yarn sized from bath type-2 demonstrated superior results in hairiness reduction, tenacity, elongation, and weaving efficiency compared to other baths, despite using a lower amount of sizing material. The findings offer valuable insights for the industry to reconsider sizing material usage in weaving in better sizing with less amount of sizing material. ANOVA was employed to assess statistical variations within the dataset. The study's objective, methodology, and implications for the industry are discussed.

© 2025 Journal of Engineering, Management and Information Technology

1. INTRODUCTION

Sizing is the most essential prerequisite of weaving. This process is affected by different issues. Many issues, like yarn parameters, process parameters, sizing materials, material properties, etc., affect the sizing process (Frag & Elmogahzy, 2009). To produce high-quality and cost-effective fabric is the primary goal of the manufacturers. So, it is vital to produce high-quality yarn those are very good in tenacity, elongation, and elastic recovery in all conditions (Malik et al., 2011). The hairiness of the staple yarn is a significant barrier to producing good-quality fabric. It also reduces the productivity of the weaving mill. Hairiness must be reduced to a considerable level to

produce quality fabric. Textile products are very diversified, such as domestic, intelligent, technical, functional, etc., which are classified based on the material used (Ahmed et al., 2021). Many material classifications include fibrous, non-fibrous, natural, manmade, synthetic, etc. Many natural fibers include cotton, jute, hemp, silk, ramie, coir, etc. (Hebeish & Guthrie, 2012). Due to its comfortability, wearability, moisture permeability, and heat conductivity, cotton is the most attractive and suitable natural material for fabric production (Mia et al., 2021). It is crucial to apply adhesive coating on the cotton yarn before weaving. The application process of adhesive coating on the cotton yarn before weaving is referred to as sizing, which

¹ Corresponding author: Abdullah Al Rakib Shikder²¹
Email: terakib1@gmail.com

increases the weaving ability of the yarn by increasing yarn strength, tension, flexibility, etc. (Sun et al. 2013, Djordjevic et al., 2019).

It reduces yarn hairiness and weakness and increases yarn smoothness, which finally helps maintain the quality of the woven fabric (Shikder et al., 2022). Many physical and mechanical properties of the warp yarn are improved due to sizing based on the applied method of sizing material. So, sizing is called the heart of weaving (Turukmane et al., 2019). The cotton fiber with extra-long staple length shows strength ranging from 25 cN/tex to 37 cN/tex, with elongation levels ranging from 6% to 8% (Yu, 2015). Different amount of starch is applied to the yarn at the time of sizing, which varies between 5% and 15% of the yarn's weight (Djordjevic et al., 2014). Nowadays, there are many modern techniques and materials for sizing cotton yarn. Many manmade polymer-based sizing materials, such as poly-acrylates, polyesters, and polyvinyl alcohols (PVAs), are popular (Kabir & Haque, 2022). This material type has reduced the coating required to achieve comparable results. However, these are not environmentally friendly and biodegradable (Nayak et al., 2002). Carboxy-methyl cellulose (CMC) sizing materials used in the industry have limited usage due to their high viscosity. CMC shows strong robustness on cellulose fiber. It combines with PVA or polyacrylic sizing agents, increasing efficiency and de-sizing properties. Also, recycling CMC is a big challenge (Xiao & Zhang, 2009). Sometimes, acrylic and acrylate-based sizing agents blend with PVA (Walker & Perkins, 1985). Warp yarn faces a complex deformation process during weaving. Warp yarn undergoes abrasion, cyclic bending, stress, impact loading, etc., in the weaving time, which influences the characteristics of warp yarn (Rahman et al., 2015).

Many constituents, like size liquor, size film, yarn characteristics, size activity, etc., are used as measurements to describe the sizing process (Ahmed et al., 2021). In size formula, many chemicals like lubricants, binders, and softeners are used for spun yarns. Also, humectants, wetting agents, and defoamers facilitate the size application to the yarn (Tanapongpipat et al., 2008). Size pick-up percentage and uniformity of sizing agent impact the weaving performance drastically. The viscosity of the sizing bath is another important factor that leads to many factors like warp speed, squeeze roll friction, size pick-up percentage, etc. (El-Sheikh, 2010).

Sizing materials should have many desirable characteristics. Hence, the selection of sizing material depends on the specific application. In other words, sizing materials selection is based on the suitability of different factors such as fiber type (cellulose, nylon, polyester), yarn type (ring spun, open end, air jet), weaving machine type (shuttle, air-jet, rapier, projectile), and fabric characteristics like style, construction, weave (plain, twill, satin) and yarn count (Kovačević & Penava, 2004; Maatoug et al., 2007a). Sizing aims to provide warp yarns with strength, flexibility, smoothness, and resistance to abrasion and static charge (Zhu et al., 2012).

Adequate sizing ensures that the fibers are secured in their original positions. An antistatic agent is applied to the sizing agent, preventing static charge for synthetic fiber-made yarn (Seboka, 2020). The size properties of the sizing agent can be changed or adjusted to gain the specific properties that ensure the weave ability of the warp yarn (Maatoug et al., 2007b, Hebeish & Guthrie, 2012). Now, sizing materials such as CMC, PVA, wax, emulsion, etc. Many bio-degradable sizing agents have been introduced by researchers (Behera & Gupta, 2008; Ahmed et al., 2021). The industry consumes many sizing agents in the bath, which remains unused after completion. This new-sized agent is drained into the environment, which is very harmful and destroys aquatic life.

This study focuses on optimizing and evaluating the required amount of sizing materials on sizing baths for industrial applications. Warp yarns were sized in different baths, varying only the sizing material amount, keeping the other material the same. Treated yarns are then evaluated based on the different physical properties like yarn count change, tenacity, elongation, viscosity, hairiness, weaving efficiency, etc., to ensure the effectiveness of using less sizing material.

2. EXPERIMENTAL DESIGN

2.1 Materials

The study was conducted in one of the renowned textile industries in Bangladesh, namely Square Textile Ltd. All the materials available on the production floor of Square Textile Ltd were used in this research. The sample yarn was composed of 65% Polyester and 35% Cotton. Two types of yarn counts were selected. Sample details are listed in Table 1.

| Sample | Count | Composition | Twist/ meter | Total Ends No. | Beam Length |
|-----------|-------|----------------------------|--------------|----------------|-------------|
| Sample -1 | 45Ne | 65% Polyester & 35% Cotton | 545 | 7168 | 4600 M |
| Sample -2 | 30Ne | | 436 | 6072 | 4962 M |

Table 1. Sizing materials detail.

The yarn samples were sized in the sizing machine using different sizing recipes. The sizing recipes are given in Table 2.

Table 2. Sizing recipe, amount, chemical name, and bath details

| Bath/Chemical | Type-1 | Type-2 | Type-3 | Type-4 |
|-------------------|---------|---------|---------|---------|
| Belsize B120 | 75 kg | 65 kg | 55 kg | 45 kg |
| PVA | 30 kg | 30 kg | 30 kg | 30 kg |
| Tam Size | 10 kg | 10 kg | 10 kg | 10 kg |
| Belsize P110 | 4 kg | 4 kg | 4 kg | 4 kg |
| Total Consumption | 119 kg | 109 kg | 99 kg | 89 kg |
| Bath Size (Liter) | 500 Ltr | 500 Ltr | 500 Ltr | 500 Ltr |

2.2 Methodology and Equipment

The process used to size the yarns mentioned above involved the utilization of the Karl Mayer Rotal Sizing Machine (BME2600/1000). The machine has a working width of 260 cm and features a double-sizing box. It is equipped with 12 cylinders, each having a diameter of 400 mm. After sizing, the yarns were unwound from the creel equipped with cross-wound bobbins that facilitated thread tension control. A tension meter and comb were positioned just before the yarn entered the size box to ensure precise yarn guiding and measurement. An immersion roller and a pair of squeezing rollers with pressure control were included in the sizing process. These components played a crucial role in the sizing operation. Subsequently, all the yarns underwent drying in a heated chamber where air circulated to expedite the drying process. The dried yarns were then wound onto a reel. To maintain consistent yarn moisture levels, a humidity measurement unit was installed at the exit of the dryer. This unit allowed for the continuous measurement of yarn moisture, ensuring that the outlet yarn moisture remained constant throughout the process.

2.3 Testing

Measurements were conducted on all the prepared samples to assess their various characteristics. To determine the yarn's physical properties, such as tenacity and extension during maximum load, the ASTM D2256-10 (2015) standard was employed. The ASTM D5647-01 (1995) and ASTM D1425-96 methods were utilized to compare the yarn's hairiness and unevenness before and after sizing.

3. RESULT AND DISCUSSION

In this research, four distinct sizing recipes were employed to size polyester-cotton blended yarn, gradually reducing the concentration of the sizing agent from type 1 to type 4. These sizing recipes were applied to two different counts of cotton yarn commonly utilized in commercial woven fabric production. The performance of all prepared samples was then evaluated, and the results of various tests conducted are presented below.

3.1 Effect of Various Sizing Formulations on Size Add-on % and Yarn Count

Figure 1 illustrates the impact of sizing materials on yarn count. Sizing materials are commonly used to enhance yarn strength, improving processing performance. These materials adhere to the yarn's surface, increasing yarn weight. As observed in this study, applying sizing materials reduced yarn count for 45 Ne and 30 Ne yarn samples. The decrease in yarn count was consistent for both types of yarn. This reduction can be attributed to the

adhesion of sizing materials to the yarns, commonly called the add-on percentage. It was found that each type of sizing bath demonstrated a different add-on percentage. Notably, the add-on percentage was relatively higher for 30 Ne yarn compared to 45 Ne yarn. Finer yarns, such as 45 Ne, have fewer fibers in the yarn cross-section, resulting in reduced uptake of sizing materials. Conversely, coarser yarns like 30 Ne exhibit higher yarn diameters, leading to a higher add-on percentage.

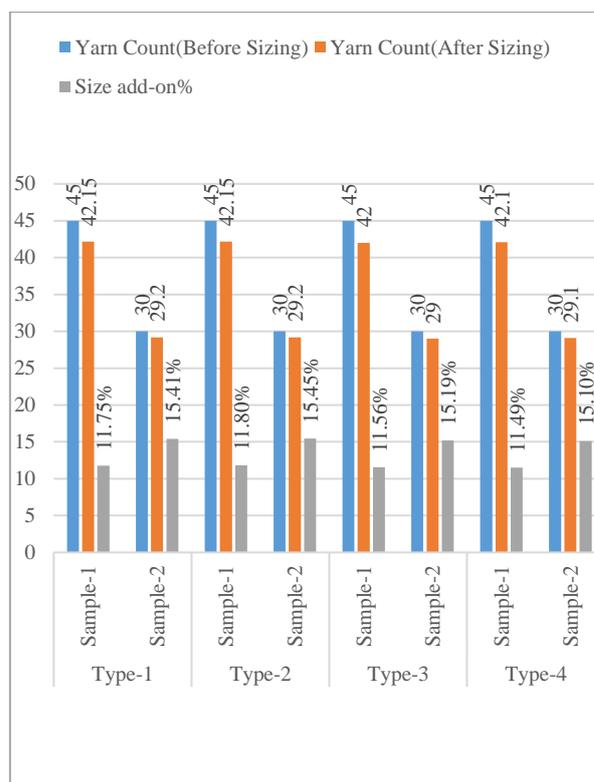


Figure 1. Effect on yarn count and size add-on %

3.2 Effect of Various Sizing Formulations on Yarn Hairiness

This study assesses the impact of sizing materials on reducing yarn hairiness, as illustrated in Figure 2. Hairiness is the quantifiable parameter defined as the length of protruding fibers within a specified yarn test length. Our results consistently demonstrate a reduction in hairiness for all samples following sizing application. The sizing materials create a protective coating on the yarn's surface, resulting in this reduction. Notably, coarser yarns exhibit superior hairiness reduction compared to finer ones across all types. The type-2 sizing bath displays the highest reduction percentages, achieving a 3.65% reduction for 45 Ne yarn and a 3.95% reduction for 30 Ne yarn, respectively. This reduction in hairiness can be attributed to the effective adhesion of protruding fibers to the yarn axis during sizing application. Consequently, the type-2 bath is preferred for minimizing yarn hairiness in textile processing.

Figure 3 provides a visual representation of this significant reduction in yarn hairiness.

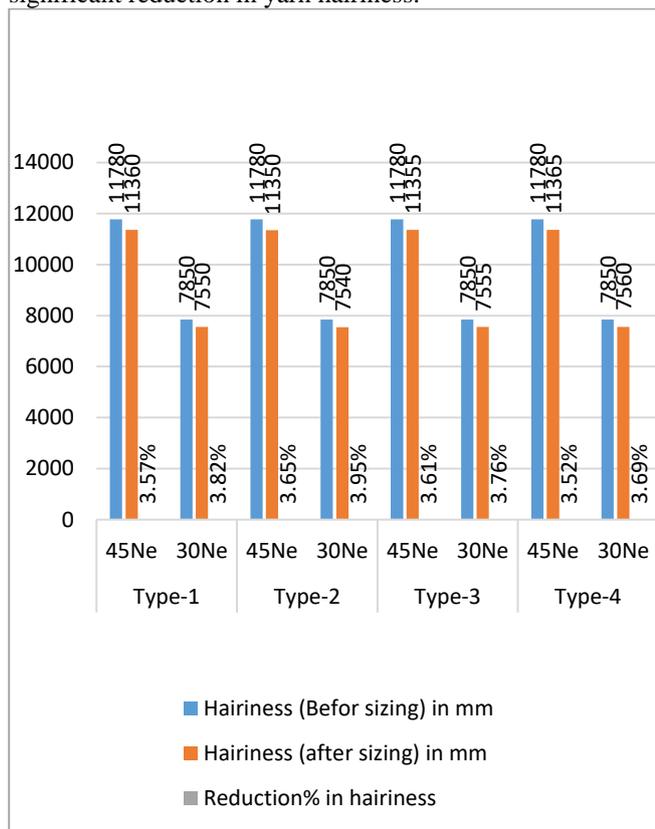


Figure 2. Effect on yarn hairiness reduction

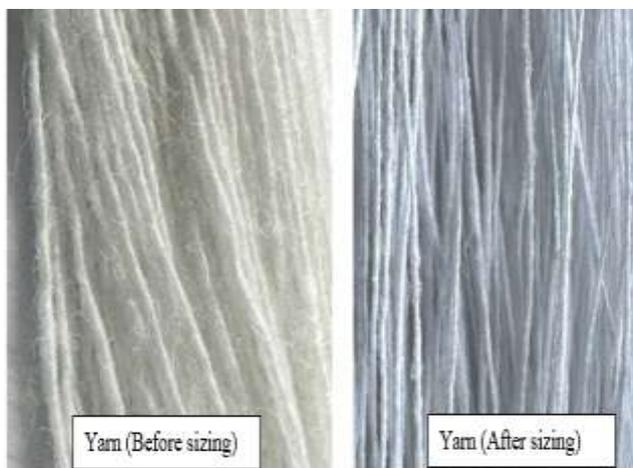


Figure 3. Effect on yarn hairiness

3.3 Effect of Various Sizing Formulations on Tenacity

In terms of tenacity, the analysis of Figure 4 indicates that finer-count yarns (45 Ne) consistently exhibit superior tenacity compared to coarser-count yarns (30 Ne) across all types of sizing baths. Notably, samples treated with the type-1 bath display slightly higher tenacity values (23.1 cN/Text for sample 1 and 18.26 cN/Text for sample 2) than those treated with other bath types. Although the type-2 bath, which previously demonstrated favorable

results, ranks second in tenacity improvement, Figure 3 reveals that all types exhibit minimal deviations in results. These findings shed light on the influence of yarn count and sizing baths on tenacity and provide valuable insights for optimizing yarn properties in textile applications.

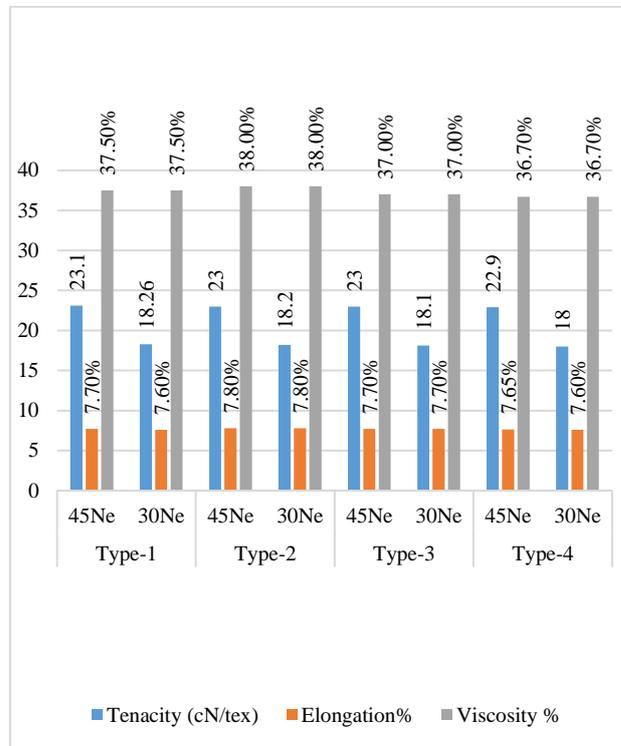


Figure 4. Effect on tenacity, elongation, and viscosity

3.4 Effect of Various Sizing Formulations on Elongation

When considering the elongation percentage of sized yarns, type-2 exhibits the highest value of elongation percentage (7.8%) for both samples. It is well-established that increased yarn stiffness leads to reduced elongation percentage. As evident from the data in Figure 4, the type-2 samples display the highest elongation percentage, suggesting that yarns treated with type-2 bath are less stiff than other samples. Conversely, type-1 and type-4 baths demonstrate the lowest values of elongation percentage, indicating greater stiffness of yarns treated with these baths.

3.5 Effect of Various Sizing Formulations on Viscosity

The relationship between sizing formulations and viscosity is multifaceted, depending on the type and concentration of the sizing agents employed. Gaining a comprehensive understanding of the effects of these formulations on viscosity is crucial for optimizing industrial processes and ensuring product quality. As depicted in Figure 4, the experimental results for sizing materials' viscosity are presented. Among the different

bath types, type-2 exhibits superior viscosity performance compared to the others, although the difference from bath type-1 is not statistically significant. Surprisingly, contrary to the commonly held belief that viscosity increases with the size of the material amount; our findings demonstrate a distinct outcome. Further research on a larger scale is warranted to elucidate the intricate relationship between sizing materials and viscosity.

3.6 Effect of Various Sizing Formulations on Weaving Efficiency

The data presented in Table 3 explains the incidence of warp cuts and machine stops while weaving running in a repair loom with 210 rpm speed. A lower number of occurrences indicates better yarn performance. The data from the graph demonstrates that the type-2 sizing material composition yields the fewest machine stops and warp cuts, resulting in the highest efficiency (86.87%). In comparison, the other three types display lower efficiencies, with values of 82.33%, 81.10%, and 79.91%, respectively, underscoring the superior performance of the type-2 bath.

3.7 Evaluation of Cost-Effectiveness

Incorporating a reduced amount of sizing material compared to standard industry practices has demonstrated notable improvements in yarn's physical and mechanical properties, as evidenced by various tests outlined above. The innovative optimization approach enhances yarn quality and significantly reduces sizing chemical consumption, as depicted in Table 2. This reduction bears significant environmental implications. Furthermore, the economic benefits are apparent, with cost reductions evident in Table 4. Particularly noteworthy is the performance of Bath Type-2, which not only exhibits favorable results in yarn properties but achieves these outcomes while utilizing 10kg less chemical compared to Type-1. Moreover, the cost-effectiveness of Type-2, costing approximately 900 BDT less than Type-1, holds great relevance for industries engaged in year-round production. Adopting Type-2 presents a dual advantage, addressing both cost-efficiency and environmental concerns, surpassing the conventional sizing recipes prevalent in Bangladesh's textile sector.

3.8 ANOVA Analysis of Weaving Efficiency

Let us take the null hypothesis of the tests that (a) the mean weaving efficiency for each type of sizing concentration is the same and (b) there is no difference among the three shifts concerning mean weaving efficiency.

- The sum of values, $T=1366.84$
- The correction factor, $C= 81284.41808$
- The sum of squares of total value = 81382.167

- The sum of the square between columns (sizing concentration) = 59.62
- The sum of squares between rows (Shift) = 27.99
- The total sum of square= 97.75

(a) The Table 5 value of F for 3 and 7 degrees of freedom at a 5% significance level is 4.346. The null hypothesis is rejected as the computed value (13.7) is more significant than the critical value. Thus, a considerable difference in the mean weaving efficiency for each type of sizing concentration is established.

(b) The Table 6 value of F for 2 and 7 degrees of freedom at a 5% significance level is 4.73. The null hypothesis is rejected as the computed value (9.65) surpasses the critical value. Hence, there is no difference among the three shifts concerning mean weaving efficiency. Therefore, from the above ANOVA analysis,

Finally, according to the ANOVA results, the choice of size concentration substantially impacts weaving efficiency, although the shifts do not significantly vary in this regard. This result can be helpful in decision-making in optimizing the sizing concentration to improve weaving efficiency.

4. CONCLUSION

The study investigated the critical factors influencing the cost of woven fabric production, focusing on sizing and weaving efficiency. Traditionally, the textile industry has followed established recipes for sizing material usage based on visual appearance alone. However, this study aimed to explore the impact of varying sizing agents on the final fabric cost while maintaining the yarn's standard physical and mechanical properties. Significant variations in results were observed through rigorous testing of two yarn counts (45Ne and 30Ne) using four different types of sizing baths. Notably, yarn sized from bath type 2 displayed superior hairiness reduction, tenacity, elongation, and weaving efficiency compared to other bath types. Remarkably, bath type-2 achieved these favorable outcomes while utilizing less sizing agent (10kg) than the traditional bath (Bath type-1), proving its cost-effectiveness. This study provides valuable insights for the industry to reconsider their sizing material usage in weaving. Wasteful practices involving excessive sizing material can be eliminated without compromising the fabric's quality. This knowledge empowers factories to optimize their sizing unit of warp yarn in the weaving section, leading to potential cost savings and more sustainable production practices. By acknowledging the significance of sizing efficiency and its impact on fabric cost, the textile industry can adopt data-driven approaches to improve its production processes and maintain competitiveness in the market. The result indicates that perfect results can be obtained using less sizing material than which industries use. So, there is no need to use more sizing material that is running practiced.

This will help reduce the cost of sizing and the price of fabric and provide big savings for the environment.

Acknowledgement: The authors are very grateful to the authority of Square Textile Mills Ltd. for helping to conduct the research in their production unit.

Table 3. Comparative result of weaving efficiency, machine stop, warp cut

| Production shift | Type-1 | Type-2 | Type-3 | Type-4 |
|-----------------------------------|----------------|----------------|----------------|----------------|
| Shift A | 83.60 % | 88.10 % | 81.10 % | 80.10 % |
| Shift B | 79.30 % | 82.60 % | 79.20 % | 79.50 % |
| Shift C | 84.10 % | 86.90 % | 83.00 % | 80.13 % |
| Average Weaving Efficiency | 82.33 % | 85.87 % | 81.10 % | 79.91 % |
| Shift A | 32 | 29 | 50 | 54 |
| Shift B | 31 | 29 | 47 | 53 |
| Shift C | 30 | 32 | 47 | 52 |
| Average Machine Stop | 31 | 30 | 48 | 53 |
| Shift A | 12 | 6 | 17 | 18 |
| Shift B | 10 | 6 | 15 | 17 |
| Shift C | 11 | 9 | 16 | 19 |
| Average warp cut | 11 | 7 | 16 | 18 |

Table 4. Comparative cost among the bath types

| Bath/Chemical | Unit price/Kg | Type-1 | Type-2 | Type-3 | Type-4 |
|---------------|---------------|-----------|-----------|-----------|-----------|
| Belsize B120 | 90 BDT | 75 kg | 65 kg | 55 kg | 45 kg |
| PVA | 420 BDT | 30 kg | 30 kg | 30 kg | 30 kg |
| Tam Size | 67 BDT | 10 kg | 10 kg | 10 kg | 10 kg |
| Belsize P110 | 261 BDT | 4 kg | 4 kg | 4 kg | 4 kg |
| Total Cost | | 21064 BDT | 20164 BDT | 19264 BDT | 18364 BDT |

*1USD=109.80 BDT

Table 5. ANOVA Analysis of Weaving Efficiency

| Production Shift | Different types of sizing concentration | | | | |
|------------------|---|--------|--------|--------|--------|
| | Type-1 | Type-2 | Type-3 | Type-4 | Total |
| Shift A | 83.6 | 88.1 | 81.1 | 80.1 | 332.9 |
| Shift B | 79.3 | 82.6 | 79.2 | 79.5 | 320.6 |
| Shift C | 84.1 | 86.9 | 83 | 80.13 | 334.13 |
| | 247 | 257.6 | 243.3 | 239.73 | 987.63 |

Table 6. ANOVA table

| Source of variation | Sum of square | Degree of freedom (df) | Mean Square | Variation Ratio or F |
|--|---------------|------------------------|-------------|---------------------------------|
| Between Column (sizing concentration) | 59.62 | 3 | 19.87 | $F = \frac{19.87}{1.45} = 13.7$ |
| Between Row (Shift) | 27.99 | 2 | 13.99 | $F = \frac{13.99}{1.45} = 9.65$ |
| Residual | 10.14 | 7 | 1.45 | |
| Total | 97.75 | 12 | | |

References:

- Ahmed, T., Mia, R., Toki, G. F. I., Jahan, J., Hasan, M. M., Tasin, M. A. S., ... & Ahmed, S. (2021). Evaluation of sizing parameters on cotton using the modified sizing agent. *Cleaner Engineering and Technology*, 5, 100320.
- Behera, B. K., & Gupta, R. (2008). Comparative analysis of desizability and retrogradation behavior of various sizing materials. *Journal of applied polymer science*, 109(2), 1076-1082.
- Djordjevic, S., Kovacevic, S., Djordjevic, D., & Konstantinovic, S. (2019). Sizing process of cotton yarn by size from a copolymer of methacrylic acid and hydrolyzed potato starch. *Textile research journal*, 89(17), 3457-3465.
- Djordjevic, S., Kovacevic, S., Nikolic, L. J., Miljkovic, M., & Djordjevic, D. (2014). Cotton yarn sizing by acrylamide grafted starch copolymer. *Journal of Natural Fibers*, 11(3), 212-224.
- El-Sheikh, M. A. (2010). Carboxymethylation of maize starch at mild conditions. *Carbohydrate Polymers*, 79(4), 875-881.
- Farag, R., & Elmoghazy, Y. (2009). Tensile properties of cotton fibers. In Handbook of tensile properties of textile and technical fibres (pp. 51-72). Woodhead Publishing.
- Hebeish, A., & Guthrie, T. J. (2012). The chemistry and technology of cellulosic copolymers (Vol. 4). Springer Science & Business Media.
- Kabir, S. F., & Haque, S. (2022). A mini review on the innovations in sizing of cotton. *Journal of Natural Fibers*, 19(13), 6993-7007.
- Kovačević, S., & Penava, Ž. (2004). Impact of sizing on physico-mechanical properties of yarn. *Fibres & Textiles in Eastern Europe*, 48(4), 32-36.
- Maatoug, S., Ladhari, N., & Sakli, F. (2007a). Evaluation of the weavability of sized cotton warps. *Autex Research Journal*, 7(4), 239-244.
- Maatoug, S., Ladhari, N., & Sakli, F. (2007b). Fatigue behavior of sized cotton warps. *Journal of Applied Sciences*, 7(18), 2706-2709.
- Malik, Z. A., Malik, M. H., Hussain, T., & Arain, F. A. (2011). Development of models to predict tensile strength of cotton woven fabrics. *Journal of engineered fibers and fabrics*, 6(4), 155892501100600407.
- Mia, R., Sk, M. S., Oli, Z. B. S., Ahmed, T., Kabir, S., & Waqar, M. A. (2021). Functionalizing cotton fabrics through herbally synthesized nanosilver. *Cleaner Engineering and Technology*, 4, 100227.
- Nayak, B., Kasetty, K. M., & Murthy, N. V. S. R. (2002). Alkaline sizing-A case study. *IPPTA*, 14(1; SPI), 67-70.
- Rehman, A., Raza, Z. A., Masood, R., Hussain, M. T., & Ahmad, N. (2015). Multi-response optimization in enzymatic desizing of cotton fabric under various chemo-physical conditions using a Taguchi approach. *Cellulose*, 22, 2107-2116.
- Seboka, N. (2020). Regression model development for showing relation between mechanical yarn stretch (%) in sizing and Warp yarn breakage (cmplx) in looms using ANOVA model. *Ethiopian journal of textile and apparel*, 1(2).
- Shikder, A. A. R., Javed Hossen Emon, J. H., Islam, S. M., Khan, M. H. K., & Siddiquee, M. A. B. (2022). Study on Reuse of Remaining Sizing Sludge of Sizing Bath for Next Weavers Beam and Focusing on Reduction the Cost. *World Scientific News*, 163, 115-127.
- Sun, S., Yu, H., Williams, T., Hicks, R. F., & Qiu, Y. (2013). Eco-friendly sizing technology of cotton yarns with He/O₂ atmospheric pressure plasma treatment and green sizing recipes. *Textile Research Journal*, 83(20), 2177-2190.
- Tanapongpipat, A., Khamman, C., Pruksathorn, K., & Hunsom, M. (2008). Process modification in the scouring process of textile industry. *Journal of Cleaner Production*, 16(1), 152-158.
- Turukmane, R., Gulhane, S., & Patil, R. B. (2019). Impact of process parameters on sizing machine performance: a review. *Melliand International*, 25(3), 182-183.
- Walker, R. P., & Perkins, W. S. (1985). Effect of sizing wax on tensile properties, abrasion resistance, and weaving performance of polyester/cotton yarn sized with polyvinyl alcohol. *Textile research journal*, 55(11), 667-671.
- Xiao, H., & Zhang, W. (2009). Current situation of environment protection sizing agent and paste. *Journal of Sustainable Development*, 2(3), 172-175.
- Yu, C. (2015). Natural textile fibres: vegetable fibres. In Textiles and fashion (pp. 29-56). Woodhead Publishing.
- Zhu, Z., Xu, D., Guo, J., & Xia, D. (2012). Comparative study on sizing properties of amphoteric starch and phosphorylated starch for warp sizing. *Fibers and Polymers*, 13, 177-184.

Abdullah Al Rakib Shikder

Department of Textile Engineering,
Uttara University, Dhaka-1230,
Bangladesh
terakib1@gmail.com

Jabed Hossen Emon

Department of Textile Engineering,
Uttara University, Dhaka-1230,
Bangladesh
jabedhossenemon@gmail.com

Rijon Saha

Department of Textile Engineering,
Uttara University, Dhaka-1230,
Bangladesh
rijonsaha@uttarauniversity.edu.bd

Md. Humayun Kabir Khan

Department of Textile Engineering,
Uttara University, Dhaka-1230,
Bangladesh
humayun11027@gmail.com

Tarikul Islam

University of Georgia,
Athens,
USA
mti@just.edu.bd
