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Research article

Impact Assessment of Sizing Parameters on the Performance of a Modified Sizing Agent in Blended Polyester-Cotton Yarn

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A B S T R A C T

Sizing is a very important pre-weaving process that dictates the warp yarn's performance in fabric manufacturing. The effect of different levels of concentration of a modified sizing agent (Belsize B120) on important performance parameters of 65/35 polyester-cotton blended yarns of two counts (45 Ne and 30 Ne) is investigated in this study. Sizing was performed with four sizing formulations on a sizing machine, and samples were tested for tenacity, elongation, initial modulus, hairiness, unevenness, abrasion resistance, and loom performance, including machine stops and warp breakage rate. Findings revealed that Type-2 formulation had the best sizing efficiency (86.87% loom efficiency), minimum warp cuts, and the best surface improvement of the yarn, and it had a lower cost as compared to Type-1. Mechanical integrity was confirmed by the fact that tenacity and elongation did not change significantly during all formulations. The results indicate that a moderately smaller sizing recipe is capable of increasing the productivity of weaving, decreasing the amount of chemicals used, and lowering the cost of production, which is a promising sustainable alternative to the textile weaving industry.

1. INTRODUCTION

The process of weaving is influenced by various factors, including the properties of the materials used, sizing materials, sizing activity, and yarn parameters [1]. Textile technologists strive to manufacture high-quality fabric cost-effectively and efficiently. There has been a considerable focus on producing better-quality yarns with enhanced characteristics such as tenacity, elongation, and elastic recovery in both dry and wet conditions [2]. One persistent demand for improving weaving quality and productivity is the reduction of hairiness in staple yarns. The market offers a wide range of textile products, including domestic textiles, technical textiles, smart textiles, and functional textiles, which are categorized based on fibrous and non-fibrous materials. Fibrous materials can be further classified into natural and manmade fibers. Natural fibers include cotton, jute, silk, hemp, and ramie, among others [3]. Cotton, in particular, satisfies a significant portion of the global clothing demand due to its excellent wearability, superior comfort, moisture permeability, and breathability [4].

To produce woven cotton fabric, it is essential to size the cotton yarn before weaving. Sizing refers to the application of an adhesive coating on the surface of the yarn, primarily aimed at enhancing the yarn's ability to withstand the weaving process, including tension, fixation, absorption, and flexing [5, 6]. Sizing also helps maintain good fabric quality by reducing hairiness, weakness, and increasing yarn smoothness and absorbency. Sizing involves various physical property modifications and is applied using different methods and designs based on specific requirements. Sizing is often referred to as the "Heart of Weaving" [7].

Most extra-long-staple cotton fibers exhibit strength ranging from 25 cN/tex to 37 cN/tex, with elongation levels ranging from 6% to 8% [8]. The amount of starch added to staple yarn can vary between 5% and 15% of the yarn's weight [9]. Modern polymer-based sizing materials, such as polyacrylates, polyesters, and polyvinyl alcohols [PVAs], have reduced the amount of coating required while achieving comparable results. However, these synthetic sizing agents are non-biodegradable and harmful to the environment. Carboxy-methyl cellulose [CMC] sizing materials used in the industry have limited usage due to their high viscosity. CMC sizes exhibit a strong grip on cellulose fibers and are combined with PVA or acrylic sizing agents to enhance efficiency and desizing properties, although recycling CMC-containing sizes remains challenging [10]. Acrylics and acrylate-based sizes are often blended with PVA.

Several factors influence the output of warp yarns on the loom, including complex deformation processes such as abrasion, cyclic bending, stress, and impact loading [11]. Until recently, a single measurement was used to describe various constituents, such as liquor size, film size, yarn characteristics, and size activity [9, 12]. In size formulas used for spun yarns, other chemicals like lubricants and binders, including blends, are employed. Humectants, wetting agents, and defoamers are also added to facilitate the application of size to the yarn [8, 13]. The amount and uniformity of size add-on significantly impact the warp's performance during weaving. The viscosity of the size bath, along with factors such as warp speed and squeeze roll friction, affects the size add-on [14].

A warp size should possess various desirable characteristics, and the selection of sizing materials depends on their specific application properties. In other words, the suitability of a sizing material for a particular application is determined by factors such as the fiber type [e.g., cellulosic, nylon, polyester), yarn type [ring-spun, open-end, air-jet], weaving machine type [shuttle, air-jet, rapier, projectile], and fabric characteristics including style, construction, weave, twist, and yarn count [15, 16]. Sizing aims to provide warp yarns with the necessary strength, flexibility, and smoothness, as well as resistance to abrasion and static charge. Effective sizing ensures that the fibers are secured in their original positions. For synthetic fibers, an antistatic agent is added to the size to prevent static charges. If certain properties of the warp yarns are insufficient to withstand the dynamic stresses during weaving, the proportion of sizing agents in the size can be adjusted to enhance those properties [17].

Currently, sizing agents primarily consist of combinations of materials such as CMC, starch, PVA, wax, emulsion, and others. However, some synthetic sizing agents are non-biodegradable and environmentally harmful [18]. This study focuses on evaluating the sizing parameters of cotton using a modified sizing agent in comparison to the commonly used sizing agent in the industry. Treated yarns and fabrics are subjected to performance evaluation based on sizing parameters, including tenacity, elongation, initial modulus, yarn hairiness, yarn unevenness, abrasion resistance, weight loss during abrasion, breaking force, extension during maximum load, and thread breakage during weaving. This experiment will help to find out whether the modified sizing recipe requires a reduced amount of chemicals, leading to cost reduction. This sustainable approach holds promise for the textile weaving industries.

2. MAIN MATERIALS AND METHODS

2.1 Materials

This study was industry-based and conducted at Square Textile Ltd. All materials used in the research were collected from the production floor of the facility. All samples were composed of a blend of 65% polyester and 35% cotton. Two yarn samples, differing in count and twist level, were selected for this study while keeping other parameters constant. Sample-1 consisted of 45 Ne yarn with a twist of 545 turns per meter, whereas Sample-2 consisted of 30 Ne yarn with 436 turns per meter. For both samples, the fabric width (57 inches), total number of ends (7168), and warp beam length (4600 m) were kept identical. The detailed specifications of the samples are presented in Table 1.

Table 1. Sample details.

Sample	Count (Ne)	Composition	Twist/ meter	Width	Total Ends	Warp Beam Length
Sample 1	45	65% Polyester & 35% Cotton	545	57”	7168	4600 M
Sample 2	30		436			

The yarn samples were sized using a sizing machine with different sizing formulations. Four types of sizing recipes were applied while maintaining a constant bath size. The detailed composition of each sizing formulation is presented in Table 2.

Table 2. Sizing recipes.

Bath Type	Sizing recipe	Total Consumption	Bath Size
Type-1	Belsize B120 - 75kg PVA - 30kg Tam Size - 10kg Belsize P110 - 4kg	119 kg	500L
Type-2	Belsize B120 - 65kg PVA - 30kg Tam Size - 10kg Belsize P110 - 4kg	109 kg	
Type-3	Belsize B120 - 55kg PVA - 30kg Tam Size - 10kg Belsize P110 - 4kg	99 kg	
Type-4	Belsize B120 - 45kg PVA - 30kg Tam Size - 10kg Belsize P110 - 4kg	89 g	

2.2 Sample preparation

The yarn samples were sized using a KARL MAYER ROTAL sizing machine (BME2600/1000) with a working width of 260 cm and a double sizing box. The machine is equipped with 12 drying cylinders, each having a diameter of 800 mm. Yarns were unwound from a creel with cross-wound bobbins to ensure uniform tension. A tension meter and guide comb were used before the size box for proper alignment and tension control. The sizing process involved immersion and squeezing rollers with adjustable pressure to ensure adequate size application. The yarns were then dried in a heated chamber with circulating air and finally wound onto a beam. A moisture measurement unit at the dryer exit was used to maintain consistent yarn moisture.

2.3 Testing

All prepared samples were tested to evaluate their physical and mechanical properties. Yarn tenacity, elongation, initial modulus, and extension at maximum load were measured according to ASTM D2256-10 (2015). Yarn hairiness and unevenness before and after sizing were assessed following ASTM D5647-01 (1995) and ASTM D1425-96, respectively. Abrasion resistance and weight loss due to abrasion were determined in accordance with ASTM D4966 [19, 20].

3. RESULT AND DISCUSSION

3.1 Effect of various sizing formulations on size add-on % and yarn count

Figure 1 presents the effect of different sizing formulations on yarn count and size add-on percentage. It is observed that yarn count decreases after sizing for both samples due to the deposition of sizing materials. Sample-1 (45 Ne) shows a size add-on of approximately 11.5–11.8%, whereas Sample-2 (30 Ne) exhibits a higher add-on of around 15.1–15.45%. Among the different sizing types, Type-2 shows the highest size add-on for both samples, while Type-4 shows a comparatively lower add-on. The results indicate that the coarser yarn (30 Ne) absorbs more size compared to the finer yarn (45 Ne), and variation in sizing formulation slightly influences the add-on percentage.

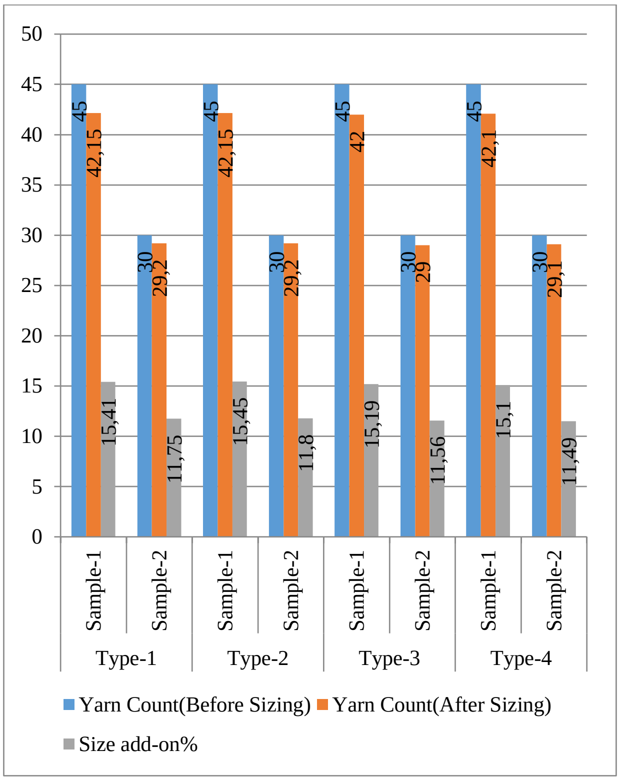

Fig. 1. Effect on yarn count and add-on %.

3.2 Effect of Yarn Hairiness

Figure 2 shows the sizing of reduced yarn hairiness in all samples. The values decreased from 7850–11780 mm before sizing to 7540–11365 mm after sizing. The reduction ranged from 3.52% to 3.95%, showing a consistent effect across all yarn types. The highest reduction was observed in Type-2 (Sample-2), while the lowest was in Type-4 (Sample-1), though the differences are small. No clear influence of yarn count (30 Ne vs 45 Ne) was found, as both showed similar reductions. This suggests that the sizing treatment works uniformly regardless of yarn fineness. The decrease in hairiness is due to the binding of loose surface fibers by the sizing layer, resulting in a smoother yarn surface.

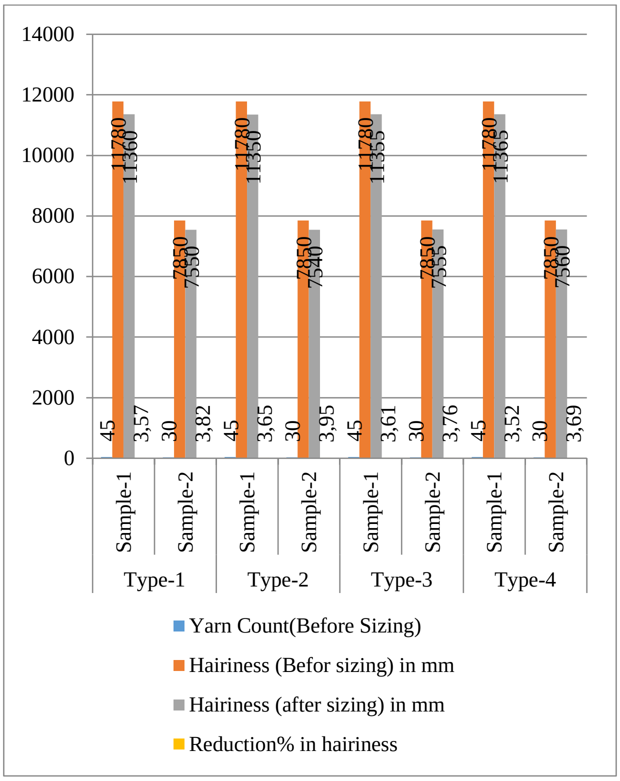

Fig. 2. Hairiness of yarns before & after sizing.

3.3 Effect on Yarn Strength

Figure 3 illustrates the effect of the applied treatment on yarn tenacity for two yarn counts (45 and 30 Ne) across four sample types. The tenacity values remain relatively stable regardless of the treatment variation. For the 45 Ne yarn, tenacity shows a marginal decline from 23.1 cN/tex in Type-1 to 22.9 cN/tex in Type-4. A comparable trend is observed for the 30 Ne yarn, where tenacity decreases slightly from 18.26 cN/tex to 18.0 cN/tex. The narrow variation range among all sample types indicates that the treatment has an insignificant impact on yarn strength. This slight reduction may be associated with minor surface or structural alterations induced during processing; however, the overall mechanical performance of the yarn remains largely unaffected.

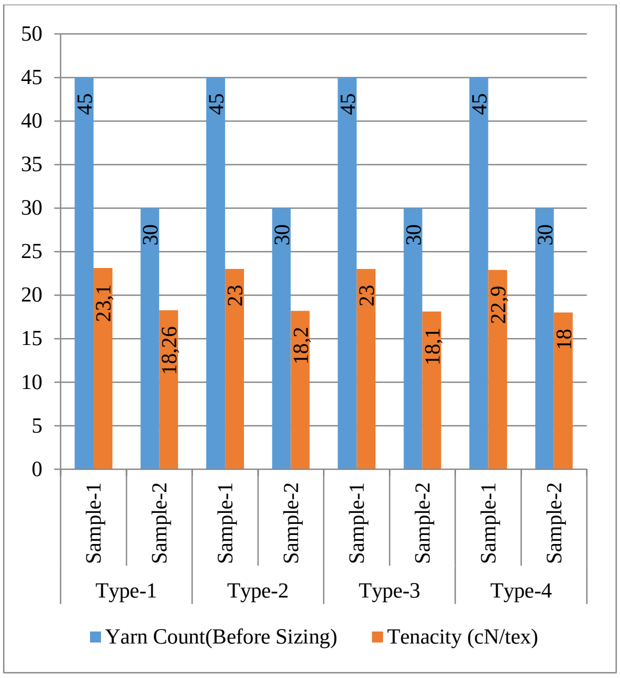

Fig. 3. Effect on Yarn Strength.

3.4 Effect on Elongation Property

Figure 4 presents the effect of the applied treatment on the elongation properties of yarn for two counts (45 and 30 Ne) across different sample types. The results indicate that elongation remains nearly constant for all variations, ranging between 7.6% and 7.8%. For the 45 Ne yarn, elongation shows a slight increase from 7.7% (Type-1) to 7.8% (Type-2), followed by a marginal decrease to 7.65% in Type-4. A similar stable trend is observed for the 30 Ne yarn, with values fluctuating insignificantly between 7.6% and 7.8%. Overall, the minimal variation suggests that the treatment has no significant effect on the extensibility of the yarn, and the structural flexibility remains largely unchanged.

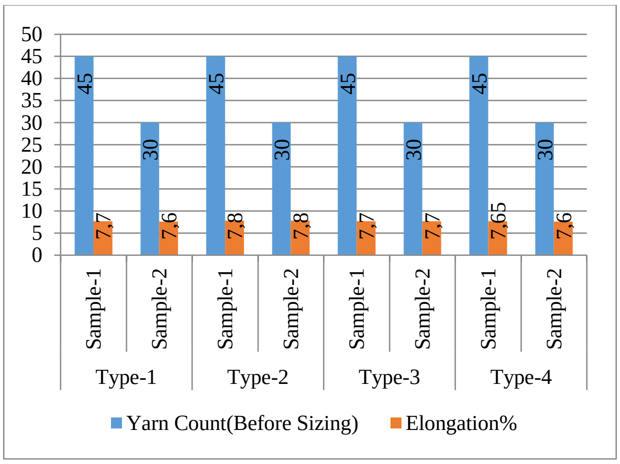

Fig. 4. Effect on Yarn Strength.

3.5 Effect on Thread breakage during weaving

It is clear from Figure 5 that the type of sizing has a noticeable impact on loom performance. Among all the samples, Type-2 performs the best, showing the highest efficiency (86.87%) along with the lowest number of machine stops and warp cuts. This suggests that the sizing in this case provided better yarn protection and smoother running conditions during weaving. On the other hand, Type-4 shows the weakest performance. The efficiency drops to 79.91%, and both machines stop, and warp cuts are the highest. This likely indicates poor sizing effectiveness, leading to more frequent yarn breakage and interruptions. Type-1 gives fairly stable results, while Type-3 appears less consistent, with a relatively high number of stops and warp cuts despite moderate efficiency. Overall, the trend is quite straightforward: as warp cuts and machine stops increase, efficiency decreases. This highlights how important proper sizing is in reducing yarn breakage and maintaining steady loom operation.

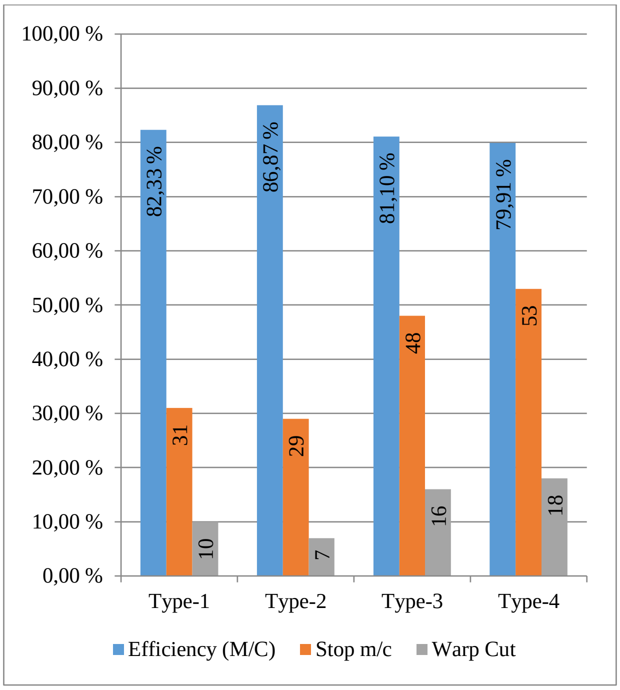

Fig. 5. Effect on Efficiency, stop m/c and warp cut.

3.6 Evaluation of cost-effectiveness

The cost analysis shows a gradual reduction in total sizing cost from Type-1 to Type-4, mainly due to the decreasing amount of Belsize B120 in the recipe as per Table 3. Type-1 has the highest cost (21064 Tk), while Type-4 is the lowest (18364 Tk). However, when these costs are compared with loom performance, a clear trade-off becomes visible. Although Type-4 is the cheapest option, it also results in the lowest efficiency and the highest number of machines stops and warp cuts. This suggests that reducing the sizing material beyond a certain level negatively affects yarn performance and increases operational losses. On the other hand, Type-2 offers a good balance between cost and performance. While its cost (20164 Tk) is slightly lower than Type-1, it delivers the highest efficiency and the lowest stoppages and warp cuts. This indicates that a moderate reduction in sizing material can optimize both cost and weaving performance. Type-3 falls in between but does not provide a clear advantage, as the cost savings are accompanied by a noticeable drop in performance. Overall, the results suggest that choosing the lowest-cost recipe does not necessarily lead to overall savings, as poor sizing increases loom inefficiencies. Instead, Type-2 appears to be the most economical option when both cost and performance are considered together.

Table 3. Cost comparison.

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

4. CONCLUSION

This experiment was completed systematically to determine the effect of different sizing agent concentrations on the performance properties of 65/35 polyester-cotton blended yarns under two count specifications (45 Ne and 30 Ne). Out of the four formulations of sizing studied, Type-2 was found to be the best recipe with the best loom efficiency (86.87%), the least machine stops, and the lowest rate of warp breakage, and at the same time achieves a quantifiable cost savings over the industry standard Type-1 formulation. The consistent result of sizing treatment was to reduce the hairiness of the yarns of all sample types by between 3.52 and 3.95 percent, and this was due to the effective attachment of the protruding surface fibers by the size film. The mechanical properties, such as tenacity and elongation, were not affected much by the various formulations, and this proves that a decrease in the concentration of the sizing agent does not affect the structural integrity of the yarn. The size add-on percentage of coarser yarn (30 Ne) was higher than for finer yarn (45 NE), as the coarser yarn had more surface area and absorbency. The cost analysis also supports the fact that Type-2 is the best compromise between material spending and the performance of the operations. Taken together, the results indicate that an optimized and reduced chemical sizing recipe can increase the productivity of weaving, reduce the environmental footprint, and cut the costs of production, which is a viable and sustainable way of providing the modern textile weaving industries with efficient and environmentally friendly production solutions.

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