

Design and development of an innovative attachment in rapier loom

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This study presents the design and development of an automated device to eliminate auxiliary selvedge in shuttleless rapier looms, thereby reducing material waste and production costs. The device grasps, cuts, and suctions the protruding weft ends after each pick insertion, effectively minimising selvedge formation without altering loom parameters. Experimental results show a 62.5% reduction in yarn waste and associated costs, while the fabric retains comparable properties in terms of yarn density, tensile strength, tearing strength, bursting strength, air permeability, dimensional stability, and crimp percentage. The attachment also functions efficiently in jacquard fabric structures, demonstrating its broader industrial applicability. The device provides a sustainable and cost-effective solution for modern textile production, enhancing material efficiency without compromising fabric quality.

Keywords: Auxiliary selvedge, Fabric quality, Material waste reduction, Rapier loom, Weaving automation

1 Introduction

Textile fabrics are made from fibres or yarns through various manufacturing techniques such as weaving, braiding, knitting, and nonwoven processes. The selection of a particular fabric depends on its aesthetic appeal, performance requirements, and cost-effectiveness. Fabrics serve a wide range of purposes, including apparel, home furnishings, and industrial products. Weaving involves the perpendicular interlacement of warp and weft yarns¹, while braiding forms fabrics by diagonally interlacing yarns². Knitting produces structures by looping yarns into horizontal rows (courses) and vertical columns (wales)³. In contrast, nonwoven fabrics are formed by bonding fibres, filaments, or polymers into flexible, porous sheets using mechanical, chemical, or thermal methods⁴.

Among all fabric manufacturing processes, weaving dominates global production, accounting for over 70% of total output⁵. India's power loom sector, in particular, continues to demonstrate substantial growth, contributing significantly to the textile industry's fabric output. Modern weaving uses advanced shuttleless looms, replacing traditional shuttle looms, which are now mostly obsolete⁶.

According to the Government of India's Ministry of Textiles (Annual Report 2017–18), the number of power looms increased from approximately 22 million units in 2008–09 to over 27 million units in 2017–18, including nearly 150,000 shuttleless looms. Power looms now contribute more than 55% of the nation's fabric production, underscoring their central role in the textile economy.

Technological innovations are pivotal in the improvement of textile machinery efficiency and applicability. For instance, Mani *et al.* (2019)⁶ reported innovations in assistive technologies for industrial sewing machines, highlighting the ongoing trend of integrating automation to enhance productivity and inclusivity in textile operations. Similarly, weaving technologies have evolved rapidly, with shuttleless looms—such as rapier, air-jet, projectile, and water-jet looms largely replacing conventional shuttle looms due to their higher speed, reduced noise, and adaptability.

A rapier loom, introduced commercially in 1972, employs finger-like carriers to transfer the weft yarn through the warp shed⁶. It is recognised for its reliability, versatility, and ability to weave a wide range of fabrics, from lightweight (20 g/m²) to heavy (850 g/m²) textiles, used across both domestic and industrial sectors^{7,8}. Currently, more than half of the

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world's looms are shuttleless, with the segment growing at an annual rate of nearly 5%, according to the International Textile Manufacturers Federation (ITMF)^{9,10}. Despite their advantages, shuttleless looms face operational inefficiencies due to auxiliary selvage formation, which remains a persistent challenge^{11,12}.

A selvage is the warp-parallel reinforced edge of woven fabric, which eliminates fraying and wrinkling. The auxiliary selvage is waste yarn cut off after weaving. It holds weft ends, assisting cutting and avoiding entanglement for smooth beat-up formation¹³. It uses additional yarn, increasing raw material expenditure and lowering profitability, as it is wasted. Research on shuttleless weaving machines identified selvage waste as 4–8 % of yarn utilised, with weft ends trimmed off, posing financial burdens to rapier weavers by incurring greater auxiliary selvage expenses¹. The auxiliary selvage keeps the projecting weft ends until beat-up, which secures them with a weave¹. Shuttleless looms applying air, water, projectile, and rapier methods appeared during the mid-20th century; modern shuttle looms are hardly manufactured^{14,15}.

Although extensive research has focused on improving loom speed, energy efficiency, and environmental sustainability, limited work addresses the reduction of auxiliary selvage waste in rapier looms^{12,16}. Recent attempts to eliminate auxiliary selvage have explored mechanisms that temporarily grip and release the weft ends for reuse¹⁷⁻¹⁹, but practical industrial implementations remain scarce.

The present study addresses this gap by designing and creating a novel attachment for rapier looms that eliminates the auxiliary selvage without disrupting the loom's existing mechanisms. The device grips the protruding weft ends after each pick insertion, cuts and suctions the remnants, and synchronises these actions with the loom's operation. This system significantly reduces yarn waste and production costs while maintaining fabric quality and weaving efficiency. The novelty of this work lies in its real-time integration of a weft control and waste elimination mechanism adaptable to both plain and jacquard weaving, offering a practical and sustainable advancement for modern textile manufacturing.

2 Materials and Methods

2.1 Materials

Following a detailed examination of the loom structure and operational requirements, the

component dimensions and design specifications were determined. The technical details of the loom used for installing the attachment are listed in Table 1.

The developed attachment for the rapier jacquard loom comprised several precisely engineered components, each designed to perform a defined function for operational reliability. The linear cam, fabricated from mild steel (MS), controlled the motion of cam followers and regulated the shedding of the gripper ends. The cam followers, made of stainless steel (SS), converted rotary motion into vertical movement of the shedding blocks through linear guide rails, ensuring accurate forward and backward motion.

Flat springs made of tin alloy maintained consistent pressure on the cam followers, enabling precise tracking along the cam profile. Stainless steel roller bearings ensured smooth interaction between the sley sword and the cam, reducing friction and vibration. Mono-blocks fabricated from stainless steel and engineering-grade plastic supported both cam and needle functions, while shedding needles guided the gripper ends to create sheds and facilitate fabric formation.

Weft ends were trimmed by a stainless steel cutter, aided by a curved cutter lifter and a cutter mono-block that controlled cutting movement through a separate linear guide rail. To hold the weft ends securely until beat-up completion, twelve reusable gripper ends made of nylon yarn were employed, supplied from an independent bobbin. Roller bearings were incorporated in all moving parts to ensure frictionless operation.

Table 1 — Specification and details of the loom used for installation of the attachment

S. No	Specification	Details
1	Loom make	Hi-Fi Tech Engineering, Salem
2	Rapier type	Double rapiers – flexible
3	Weft insertion type	Rapier
4	Shedding type	Cam shedding
5	Beat-up mechanism	Link beat-up mechanism
6	Loom width	142 cm
7	Speed	230 rpm
8	Picking type	Eccentric drive with segment gear
9	Warp yarn	20.4 tex cotton
10	Weft yarn	22.6 tex cotton
11	Selvage type	Leno selvage
12	Temple type	Ring temples
13	Weave type	Jacquard
14	Ends per cm (EPC)	28
15	Picks per cm (PPC)	26
16	Number of ends in auxiliary selvage	14 on both sides

This integrated configuration of precision-engineered components enabled stable weaving performance, improved yarn utilisation, and consistent mechanised control of weft ends, even for complex jacquard structures.

2.2 Method of Setting the Attachment

2.2.1 Setting Up and Commissioning the Loom

A domestic rapier loom (specifications in Table 1) manufactured by Hi-Fi Tech Engineering Works, Salem, Tamil Nadu, was selected for installation. After mounting and aligning the mechanism, a series of trial runs was conducted to produce fabric without

auxiliary selvedge formation. Approximately 15 m of fabric were woven under identical operational parameters as those used for fabric with auxiliary selvedge. The installed attachment and its components are illustrated in Fig. 1.

2.2.2 Sequence of Operations Based on Loom Timing

The rapier movements were synchronised, with both rapiers initiating motion at the same crank position. The mechanism's operation was coordinated with the loom's primary motion timing, using the crankshaft's angular rotation as a reference. The sequence of mechanism operations in relation to loom

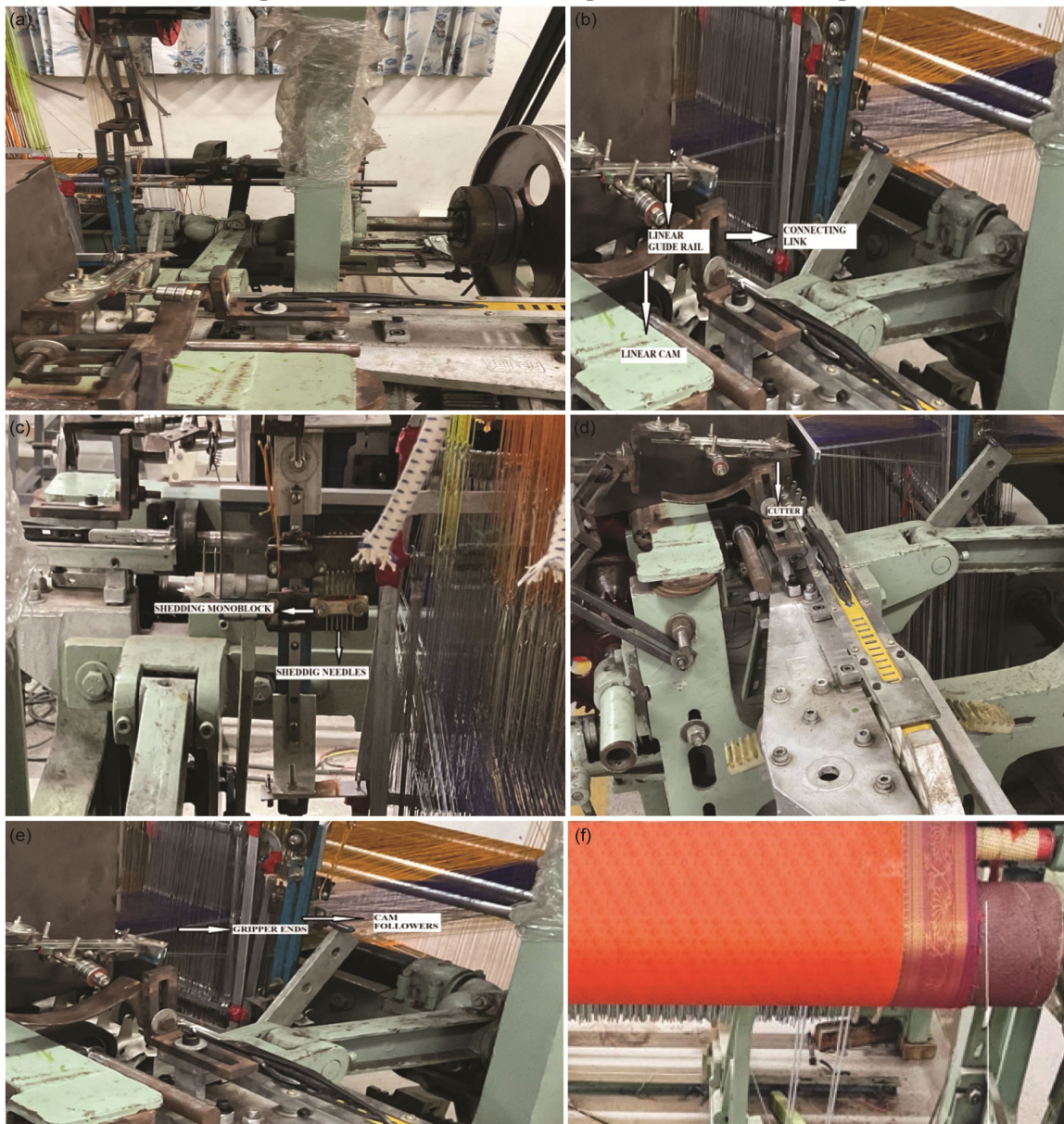


Fig. 1 — Developed device on the rapier loom and its setting (a) attachment installed on the loom, (b) linear cam setting, (c) setting for shedding, (d) setting for cutter, (e) gripper weft yarns and (f) fabric produced without auxiliary selvedge

timing is summarised in Table 2, while Fig. 2 shows the degrees of crankshaft rotation during one complete cycle.

2.2.3 Setting of the Mechanism

Precise adjustments were made between key components to ensure smooth and efficient performance. The ideal settings for the mechanism, in terms of clearances and distances between its sections and the associated loom components, are as follows:

The linear cam was adjusted to travel a distance of 140 mm between the front and back centre positions,

where a maximum shed height of 70 mm could be attained. Shedding blocks were adjusted to travel 70 mm, matching the maximum shed height required for the gripper ends.

Critical clearances were provided to allow smooth operation: a 20 mm clearance between the outer end of the cam and the first warp stop motion bar at the back centre, and 60 mm spacing between the inner end of the cam and the sley when the cam was in the advanced position. Follower rollers were 110 mm apart when the shed was open and adjusted 40 mm apart in the closed position from the gripper ends.

Table 2 — Sequence of mechanism operations corresponding to loom timing

S. No.	Degrees of crankshaft rotation	Normal loom function	Sequence of mechanism operations
1	90° (front centre)	Sley positioned at the front centre, beat-up completed, warp shed crossed, and rapiers at rest	Linear cam in forward position grips protruding weft ends; cutter at rear and open.
2	90° - 180°	Sley moves backwards, rapiers at rest, and warp yarns shift to create the next shed	Cam moves backwards, cam followers and shedding monoblocks set up the next shed for the gripper ends. Gripper ends continue to control the weft.
3	180° (bottom centre)	Sley positioned between the front and back centres. As the shed opens for the next pick, rapiers initiate movement	Cutter moves forward, trimming weft 10 mm from the edge; grippers release cut ends and form the next shed. Suction system removes the cut weft ends.
4	180° - 270°	Sley moves close to the back centre, shed opens, rapiers move into the shed	Linear cam moves back to its farthest position from the reed and gripper shed opens as rapiers move into it.
5	270° (back centre)	Shed fully opened, sley positioned at the back centre. Weft passes from the giver rapier to the taker rapier	When the linear cam is at its farthest position from the reed, the shed for the gripper ends is open, allowing the weft to transfer between the giver and taker rapiers.
6	270° - 360°	Sley positioned between back and front centres, warp shed begins to close, rapiers retreat from warp shed	Linear cam moves forward, cam followers and shedding blocks move toward each other. Shed formed by the gripper ends begins to close.
7	360° (0°) (top centre)	Sley between back and front centres, warp shed closing, rapiers continue to retreat from warp shed	Linear cam moves forward toward the reed, shed continues to close as the rapier retreats from the warp shed.
8	0° - 90°	Sley returns to front centre, warp shed closes and begins crossing, rapiers exit the shed after releasing the weft	Linear cam near forward position, gripper ends close around the weft before the rapiers release. Weft ends held by grippers.

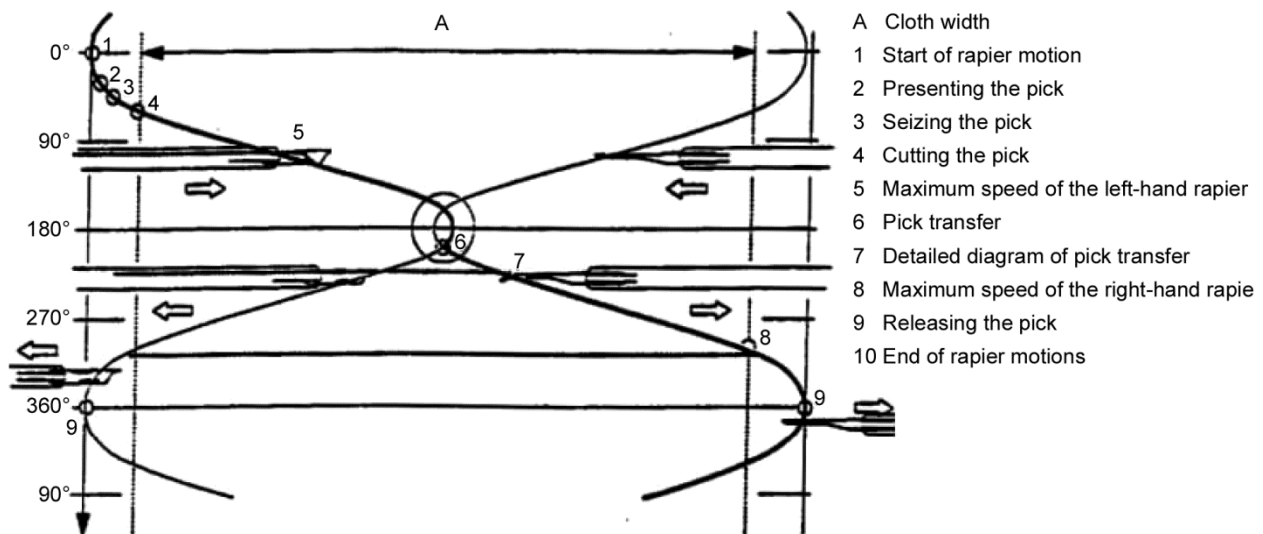


Fig. 2 — Degrees of crankshaft rotation

The cutter was finely adjusted with a 9 mm space from the reed in the front centre and could shift back 30 mm to provide clearance for the shed. Other clearances were a 20 mm gap between the temple and the cutter guide rail, a 4 mm gap between the temple and the cutter, and an 85 mm space between the cutter lifter and roller bearing in the rear. Cutter blades fully opened were 15 mm apart, travelling within the 30 mm loom front displacement of the roller bearing. Other fine tolerances were a 3 mm gap between the cutter opening roller and fixed blade, and a 15 mm length for follower rollers within the cam. Lastly, suction devices were configured with a 10 mm gap from the gripper tips and 40 mm between the cam and guide rail for the mono-block shedding.

These calibrated settings ensured stable gripping, precise cutting, and reliable suction of weft ends, resulting in minimal yarn wastage and consistent fabric quality.

3 Results and Discussion

The mechanism is effectively mounted and set up on the rapier loom, enabling the production of fabric without an auxiliary selvage. The quality of fabrics produced with and without the auxiliary selvage is evaluated and compared.

3.1 Crimp Percentage, Yarn Density and Areal Density

The crimp percentage refers to the degree of waviness in yarn within the woven structure. As shown in Fig. 3 (a), a marginal increase in crimp percentage is observed in fabrics woven with the attachment. This slight rise is attributed to reduced weaving tension, allowing the yarn to assume a more curved path. The results are consistent with previous findings reported by the authors¹².

Figure 3 (b) shows the yarn density of fabrics produced with and without the attachment. The fabric woven with the attachment exhibits a slightly lower yarn density, likely due to the increased yarn waviness that occupies more space within the structure.

Areal density represents the mass of fabric per unit area and indicates the compactness of yarn packing. As depicted in Fig. 3 (c), fabrics woven with the attachment exhibit a marginally higher areal density, corresponding to the increased crimp percentage that results in tighter yarn packing.

3.2 Tensile and Tearing Strength

Tensile strength, a critical measure of a fabric's resistance to tension and elongation, is evaluated

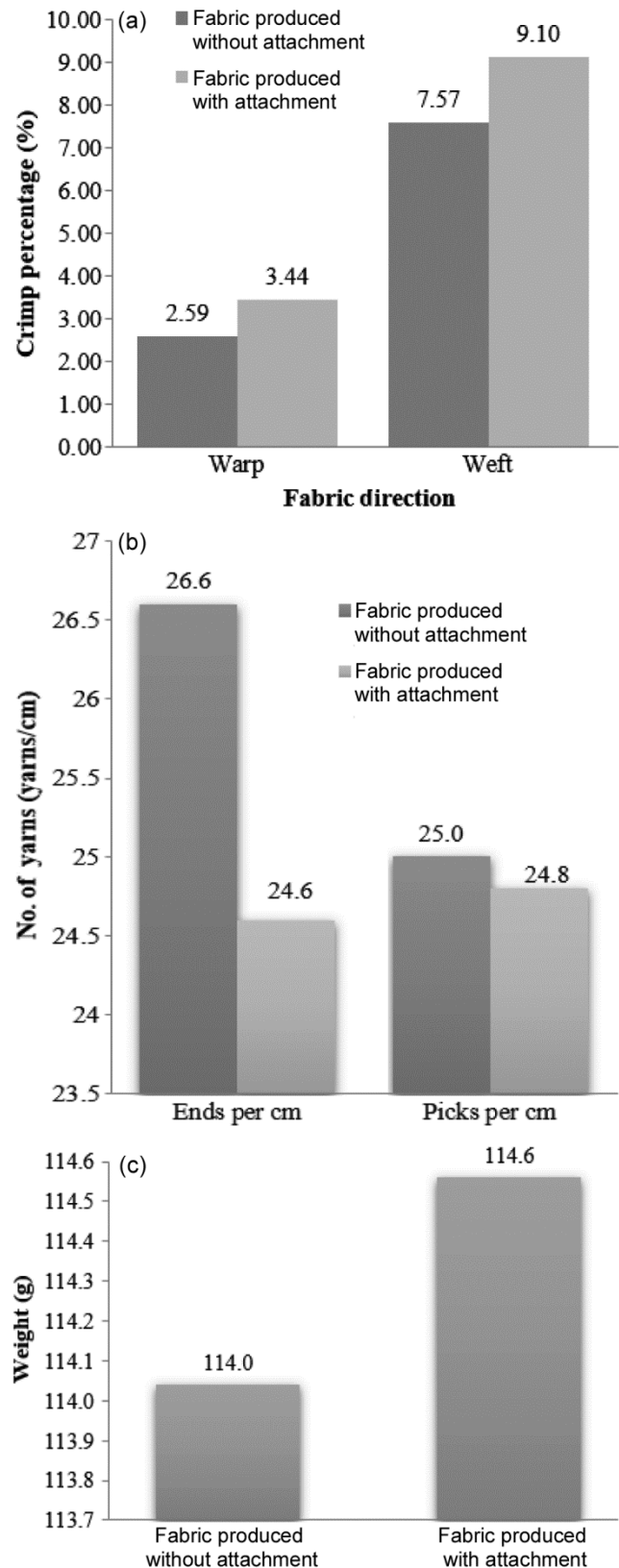


Fig. 3 — Effect of attachment on (a) crimp percentage, (b) yarn density and (c) areal density

according to ISO 13934-1:2013. Results in Fig. 4 (a) reveal a slight increase in tensile strength in fabrics produced with the attachment, attributed to the enhanced interlacing effect from higher yarn crimp. Similar results are reported in literature¹².

Tearing strength is the force required to tear the fabric apart once a small initial cut has been made. It measures the fabric's resistance to tearing under controlled conditions. The tearing strength was determined using the Elmendorf method as per ISO 13937-1:2001. As shown in Fig. 4 (b), the fabric woven with the attachment exhibits marginally lower tearing strength. This reduction results from increased crimp, which decreases the direct load-bearing efficiency of yarns that are no longer perfectly aligned along the force direction, consistent with previous work¹³.

3.3 Bursting Strength

Bursting strength measures the fabric's resistance to rupture under multidirectional pressure. As shown in Fig. 5 (a), a minor increase in bursting strength is observed in fabrics woven with the attachment. This enhancement is associated with higher crimp, which enables the yarns to redistribute load more uniformly. The trend aligns with earlier published research¹² by the authors.

3.4 Air Permeability

Air permeability is a measure of the ease with which air can pass through a fabric. The air permeability was evaluated at 125 Pa pressure for a test area of 38 cm² in accordance with ASTM D737-2004 (CFM). Fig. 5 (b) shows that the fabric produced with the attachment exhibits slightly higher air permeability. The marginal increase results from the slightly open structure caused

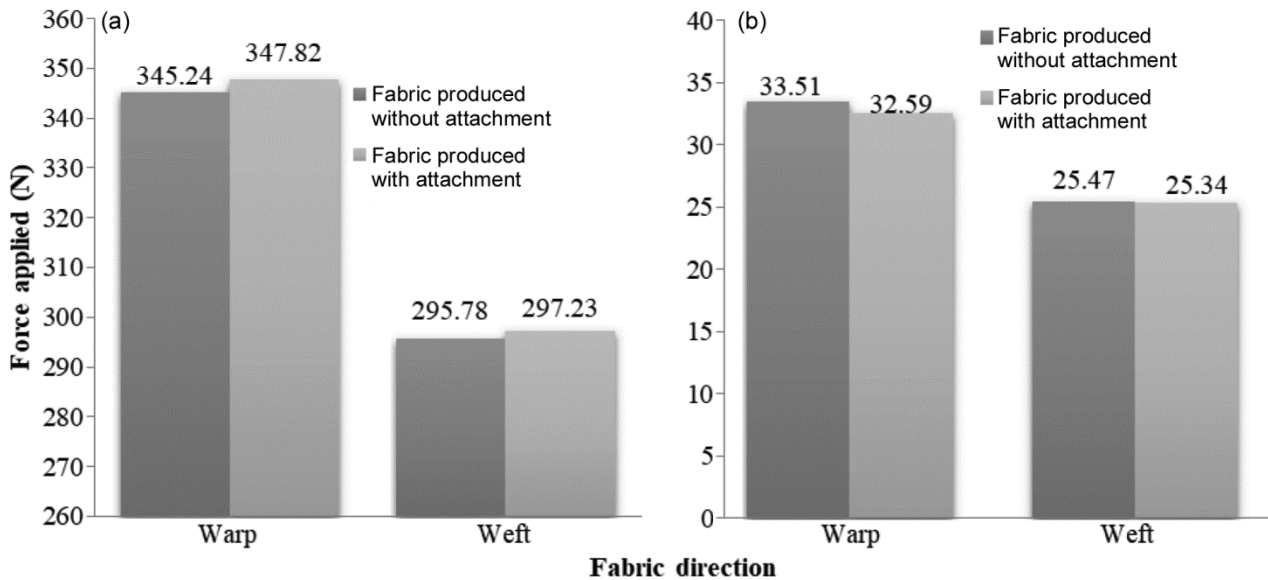


Fig. 4 — Effect of attachment on (a) tensile and (b) tearing strengths

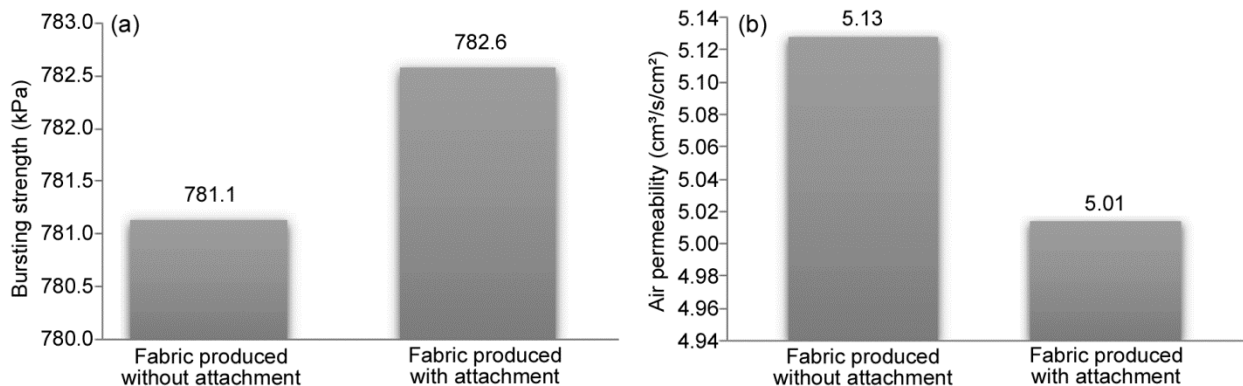


Fig. 5 — Effect of attachment on (a) bursting strength and (b) air permeability

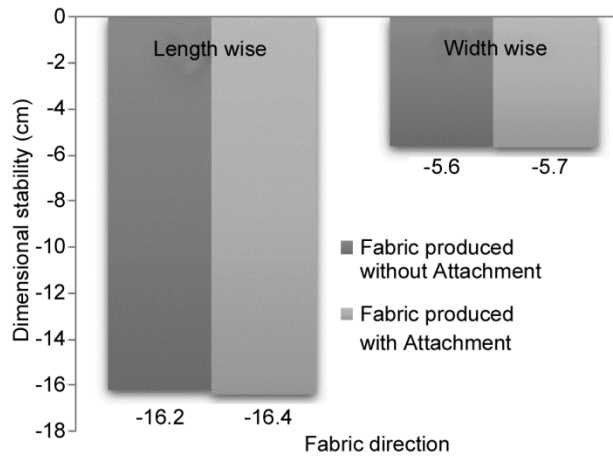


Fig. 6 — Effect of attachment on dimensional stability

by increased yarn curvature, which forms marginally larger inter-yarn pores.

3.5 Dimensional Stability

Dimensional stability of a fabric refers to its ability to maintain its original dimensions and shape under various conditions, especially during use and care processes such as washing, stretching, ironing, or exposure to environmental factors. Figure 6 shows fabrics woven with the attachment show slightly reduced dimensional stability. This is due to the ability of wavy yarns to straighten under tension, causing minor stretching. The finding is consistent with the previous work¹².

Comprehensive evaluations covering yarn density, areal density, tensile strength, tearing strength, bursting strength, air permeability, dimensional stability, and crimp percentage indicate negligible differences between fabrics woven with and without the attachment. As reflected in the graphical analyses, the attachment does not adversely affect the structural or mechanical integrity of the fabric. This stability is attributed to the precise gripping and release of weft yarns by the attachment, which prevents uneven tension and distortion. The results reinforce earlier conclusions by Thangamani and Sundaresan (2022)²⁰, demonstrating that well-engineered auxiliary systems in shuttleless looms achieve substantial material savings while maintaining fabric strength, uniformity, and performance²¹.

3.6 Yarn Waste Reduction and Economic Impact

In the Tamil Nadu textile sector, the average yarn waste due to auxiliary selvedge is approximately 800 g per loom per shift of 8 h. After installing the developed attachment, the yarn wastage is reduced to

300 g, yielding a saving of about 500 g per loom per shift. Assuming an average yarn cost of ₹400 per kg, this equates to a saving of ₹200 per loom per shift, or ₹5000 per shift for a shed operating 25 looms.

The developed attachment results in an approximately 62% reduction in yarn wastage, significantly improving sustainability and cost efficiency. The device reduces raw material usage by eliminating the auxiliary selvedge without affecting loom operation or fabric characteristics. These findings align with published study²⁰ that demonstrates similar resource savings through enhanced weft handling and timing synchronisation. Notably, the present attachment proves effective even for complex jacquard structures, extending its utility beyond basic weave types examined in earlier research¹².

Unlike previous designs that often compromise quality to achieve economy, the present attachment ensures both waste reduction and fabric integrity. Earlier studies primarily focus on plain weaves¹², while the current work successfully integrates the mechanism into jacquard weaving, maintaining high-quality output with measurable material savings. The study establishes a new benchmark for sustainable and efficient weaving automation in shuttleless loom systems.

4 Conclusion

This study demonstrates the successful implementation of a novel attachment on rapier looms, enabling fabric production without an auxiliary selvedge while achieving approximately 62% reduction in yarn wastage, resulting in significant raw material savings and cost efficiency. Comparative analyses show little to no difference in fabric quality between fabrics produced with and without the auxiliary selvedge. In some parameters, fabrics woven with the attachment perform slightly better, with small increases in crimp contributing to marginally higher tensile and bursting strengths. This improvement is attributed to slightly lower weft tension during weaving, which enhances crimp formation and positively influences fabric properties such as air permeability. The attachment demonstrates successful application in complex jacquard fabrics, highlighting its versatility and industrial applicability beyond simpler weaves explored in earlier studies. Overall, the attachment provides significant yarn savings and waste reduction without sacrificing and, in some instances, improving fabric performance, constituting a significant leap in cost-effective, sustainable textile production.

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