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Preventing Garment Waste at Source: Elastane Feeding Angle in Tights Knitting

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Abstract— Garments rejected during manufacture are an under-examined stream of textile waste. They carry the full environmental burden of fibre production, dyeing, knitting and finishing, but unlike post-consumer clothing they are discarded before delivering any service. Elastane-containing garments are particularly problematic, because elastane obstructs both mechanical and chemical recycling of blended textiles. This study asks whether elastane damage in knitted tights can be reduced at source by altering the geometry of the yarn path between creel and feeder. Quality-assurance records at a Sri Lankan hosiery manufacturer attributed 25% of elastane damage to the feeding system and, within that group, 44% to yarn path behaviour. Three feeding angles, 38.7°, 45.0° and 50.2°, were derived from a survey of 60 production machines and trialled with all other variables held constant. Screening over 100 pairs per angle gave defect rates of 1.0% at 45.0°, 1.5% at 38.7° and 5.0% at 50.2°. In seven days of continuous production, 45.0° recorded 6 defects in 720 pairs (0.83%) against 17 in 745 pairs (2.28%) at 38.7°, a statistically significant difference ($\chi^2 = 4.08$, df = 1, $p = 0.043$). Applied to the 351,042 pairs produced in 2025, of which 3,962 were lost to elastane damage, the trial rate corresponds to approximately 1,040 finished garments not discarded each year. The intervention requires repositioning a single yarn guide and no capital investment, indicating that process geometry is an accessible, under-used lever for waste prevention in apparel manufacturing.

Keywords— textile waste prevention; circular economy; elastane; knitting process optimisation; defect reduction

I. INTRODUCTION

Discussion of textile circularity concentrates largely on what happens to clothing after use. Losses also occur earlier, before a garment has left the factory: items rejected at final inspection. These items are complete, or nearly so, when they fail, so the fibre, water, energy, chemicals and labour consumed in making them are already spent. Preventing a defective garment is therefore worth more, in resource terms, than recovering the same mass of material at end of life. The problem addressed here is one such loss: elastane damage in knitted tights, a defect that renders a finished garment unsaleable and that no downstream recovery route recaptures.

Garments containing elastane sharpen the problem. Elastane is chemically stable and highly elastic, which causes fibre entanglement and equipment blockage in mechanical recycling and resists the degradation routes used for other fibres, so blends containing it are among the most difficult textile waste to process [1]. A defective pair of elastane-blend tights has, in practice, no attractive downstream route: it is downgraded or discarded. Reducing the number produced is the only intervention that avoids the waste rather than relocating it.

In knitted tights, stretch and fit depend on an elastane yarn plated into the welt behind a non-elastic ground yarn. Damage to that component, recorded in production as the two defect classes overstretch and wavy welt, is an irreversible loss of extension and recovery; the yarn cannot be repaired, and affected pairs are downgraded or scrapped [2]. Elastane is most susceptible to such damage in the path between creel and feeder, where yarn input tension (YIT) is established before loop formation. For a yarn sliding over a guide, the capstan relation $T_2 = T_1 e^{\mu\theta}$ relates delivered tension to the deviation angle θ at the guide and the friction coefficient μ [3]. With the incoming segment near horizontal, θ equals the feeding angle, so tension delivered to the feeder rises with that angle. Elastane must also be delivered under positive tension if it is to feed at a steady rate, and both YIT level and YIT variability govern defect generation even where a positive feed is fitted [4]–[6]. Feeding geometry is therefore bounded from both directions, and damage is expected at both extremes of feeding angle, with a minimum at an intermediate value.

General knitting faults have been catalogued extensively [7], but the geometry of the creel-to-feeder path has received little direct study under commercial conditions. The gap addressed here is therefore twofold: the feeding angle is a setting every machine has and none specifies, and no published work treats it as a waste-prevention measure rather than a quality one.

The distinction matters beyond the factory. Sustainable Development Goal 12.5 targets a substantial reduction in waste generation through prevention by 2030, and EU textiles policy [11] introduces mandatory extended producer responsibility

together with a ban on destroying unsold textiles, which applies to large enterprises from July 2026. For exporters to that market, waste arising inside the factory is increasingly something buyers expect to see measured and reduced, and defect-driven loss is the part of it a manufacturer controls directly.

This study tests whether the elastane feeding angle is associated with the incidence of elastane damage, and quantifies the garment waste that a change in that geometry would avoid. The null hypothesis is that the incidence of elastane damage is independent of feeding angle (H_0); the alternative is that it varies with feeding angle (H_1).

II. Background

A. Yarn input tension and knitted defect generation

The mechanical state of a yarn as it reaches the needles is governed by the tension established along the delivery path. Vasconcelos et al. [4] showed that tension variations arising before the positive feed still influence the characteristics of the resulting knitted fabric. That matters here, because it locates the sensitive region upstream of the feed device itself, in the creel-to-feeder path this study manipulates. Hossain and Islam [6] modelled dynamic yarn input tension on circular weft knitting machines with positive storage feeding. They found it varies through the machine cycle rather than holding a set value, so a nominal tension setting does not describe what the yarn experiences. Iqbal et al. [5] evaluated yarn damage through the knitting process and reported that damage accumulates progressively as the yarn passes through successive elements, which implies that conditions early in the path carry forward.

Factory-level studies confirm both the method and the target. Sadi et al. [8] tracked twenty defect types over twelve months in a weft-knitting mill and found that five of them accounted for roughly 90% of all faults, elastane breakage among them, using the same Pareto and cause-and-effect tools applied here. Their remedies, however, again concern yarn quality, machine maintenance and contamination control rather than the path the yarn takes to the feeder.

Taken together these results suggest that the delivery geometry preceding the feeder is a plausible site of damage, but none of them varies that geometry directly. Taher et al. [7] catalogue knitting faults comprehensively by appearance, cause and remedy, yet the remedies offered for elastane-related faults concern yarn selection, machine speed and needle condition rather than the path the yarn takes to the feeder. The gap this study addresses is therefore narrow but practical: the feeding angle is a setting every machine already has, it is never specified, and its effect has not been measured under production conditions.

B. Elastane, damage and recyclability

Jovanović et al. [2] examined how elastane content governs the elastic properties of knitted fabrics under cyclic loading, confirming that the elastane component, not the ground yarn, determines recovery behaviour; damage to it is therefore not cosmetic but functional, and is what renders an affected garment unsaleable. At end of life the same component becomes an obstacle: Zhu et al. [1] describe how the high elasticity and thermoplasticity of spandex cause fibre entanglement and equipment blockage in mechanical recycling, while its chemical stability resists the degradation routes used for other fibres. Abrishami et al. [9] reach a comparable conclusion from the recovery side, identifying contamination, blend separation and economic feasibility as persistent barriers to textile recycling at scale. Elastane blends therefore sit awkwardly in circular systems from both ends, which is what makes prevention during manufacture more valuable per garment than recovery afterwards.

C. Waste generated before the garment is sold

Work on pre-consumer textile waste concentrates on the cutting room. Nasrin Haq and Alam [10] show that offcuts from a single t-shirt order can be re-cut into roughly 2,200 toddler garments, avoiding recycling cost altogether. Such reuse is attractive because the material is clean, sorted, single in composition and available in quantity at one point in the factory.

Garments rejected at final inspection satisfy none of those conditions. They are complete rather than offcut, so they cannot be re-cut into a smaller product; their fault is functional rather than dimensional, so the damaged welt cannot simply be trimmed away; and they carry every process input the saleable garments carry. What they do have, which cutting waste often lacks, is a count: every rejected pair is already recorded by style, defect class and date in the quality system. A stream that is harder to reuse but easier to measure is well suited to prevention rather than recovery, and that is the space this study occupies.

III. Materials and Methods

A. Study site and identification of the loss stream

The study was carried out at a commercial hosiery manufacturing facility in Sri Lanka, identified here as ABC Company Ltd to preserve commercial confidentiality, using the company's internal quality-assurance records and physical inspection of rejected garments. Seven months of defect records (January–July 2025) were analysed. A style-wise breakdown identified the style carrying the highest elastane damage count, which was selected for the trials. Rejected garments of that style were collected and classified, confirming overstretch and wavy welt as the dominant forms. A cause-and-effect analysis and a Pareto ranking then located the origin of the damage within the process.

B. Definition and measurement of the feeding angle

The feeding angle was defined as the angle between the horizontal and the yarn segment running from the last guide to the feeder. It was obtained from two measured lengths: the vertical drop between guide and feeder eyelets, and the horizontal offset between them. Both were taken with a steel rule to the nearest 0.5 cm with the machine stationary. The angle follows as $\alpha =$

$\tan^{-1}$ (vertical drop / horizontal offset), and the free yarn length is the hypotenuse of the same triangle. A benchmark was taken from Lonati SBYS machines in the same facility, which the factory's 2025 defect records show to have fewer elastane defects; their creel-to-feeder arrangement (45 cm drop over a 45 cm offset) gives a balanced angle of 45°. That platform also differs in guide and spring count, so the angle was treated as a benchmark to test rather than a setting to adopt.

So that the deviated conditions represented the factory, guide heights and horizontal offsets were measured on 60 conventional Soko machines. Those set above the benchmark and those set below it were averaged separately, and the two averages defined the deviated conditions. They placed the last guide 12 and 8 cm above the feeder, against 10 cm at the benchmark, with the horizontal offset 10 cm and the feeder eyelet 125 cm above floor level throughout. Applying $\alpha = \tan^{-1}$ (vertical drop / horizontal offset) to these averaged measurements gives feeding angles of 38.7°, 45.0° and 50.2°, and free yarn lengths of 12.81, 14.14 and 15.62 cm (Fig. 1).

Three angles were tested rather than a finer series because this is a first screening of a factor that has not previously been examined under production conditions. At this stage the questions are whether feeding angle affects damage, and which of the settings already in use performs best; locating the true optimum between them is a separate question. A benchmark with one deviation on either side is the smallest design that can answer these, and it allows damage to rise in either direction rather than assuming a single trend. The two deviated levels were fixed by the floor survey rather than selected, so all three conditions are ones that occur in practice. Locating a minimum requires a finer series of angles and belongs to a second stage of work, which is why 45° is reported as the best of the three tested rather than an optimum.

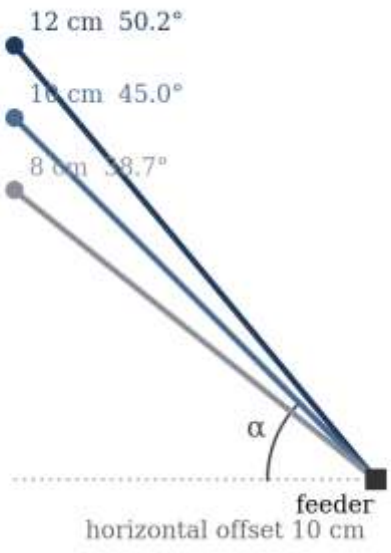


Figure 1. The three feeding-angle configurations, drawn to scale.

TABLE I. GEOMETRY OF THE THREE FEEDING CONFIGURATIONS: GUIDE HEIGHT ABOVE THE FEEDER, HORIZONTAL OFFSET, RESULTING ANGLE AND FREE YARN LENGTH

Setting	Guide height (cm)	Offset (cm)	Angle (°)	Free yarn (cm)
Shallow	8	10	38.7	12.81
Benchmark	10	10	45.0	14.14
Steep	12	10	50.2	15.62

C. Controlled variables

Feeding angle was the only factor deliberately altered. The following were held constant: cylinder diameter (3¾ in / 95 mm), needle count (144 needles), machine speed (280 rpm), elastane linear density (120 denier), yarn lot (DVP01), number of guides (2) and tension springs (1). All trials ran on single-cylinder Soko hosiery machines in normal production.

D. Trial design

Production and defects are counted in pairs, one pair being a garment of two legs, so a defect value of 0.5 denotes a single damaged leg. In Trials 1 and 2 a single machine, selected for stable running condition, was re-set to each configuration in turn by adjusting the height of the second (last) yarn guide. Trial 1 (19–24 January 2026) screened all three configurations over 100 pairs each. Trial 2 (29 January – 3 February 2026) repeated the two lower angles over a further 100 pairs each; 50.2° was not repeated, the Trial 1 result for that level being unambiguous. Trial 3 (5–12 May 2026) instead ran the two remaining configurations concurrently on two machines, one per angle, over the same seven days of normal production, recording 720 pairs at 45.0° and 745 at 38.7°. Every pair was inspected by trained quality-assurance staff under the factory's standard 100% inspection routine, defects being recorded against the existing factory defect catalogue. Elastane damage was counted as a single category comprising both overstretch and wavy welt.

Each arrangement leaves a different factor uncontrolled. In Trials 1 and 2 the angles ran in sequence on one machine, so any change in conditions over those days is mixed in with the angle effect. In Trial 3 they ran at the same time on two machines, so any difference between the machines is mixed in with it instead. Because 45.0° gave the lower defect rate under both, neither uncontrolled factor alone accounts for the outcome, and the agreement between the two arrangements supports attributing the difference to the feeding angle. On their own the screening runs are too small to be conclusive, and the seven-day trial carries the statistical weight.

E. Defect classification and inspection

Elastane damage is recorded by the factory as two visible defect classes. Overstretch appears where the elastane has been extended beyond its recoverable range during feeding, leaving a welt that no longer returns to its relaxed width; wavy welt appears where irregular delivery has produced uneven loop lengths along the welt course. Both are judged against the

factory's existing defect catalogue by inspectors already trained on it, so no new classification scheme was introduced for the trials and the counts remain comparable with the facility's historical records. Rejected garments from the selected style were additionally collected and inspected physically at the start of the study to confirm that these two forms accounted for the elastane damage observed. Because the two were not tallied separately during the trials, results are reported as a single elastane damage category.

F. Statistical analysis

Independence was tested on the Trial 3 data by a chi-square test with Yates' continuity correction ($\alpha = 0.05$), with effect size expressed as a risk ratio with a 95% confidence interval. The test was applied at pair level rather than leg level, since the two legs of a pair share a machine, a yarn package and a moment in production. Annual waste-prevention potential was estimated by applying the observed trial rate to the facility's 2025 production volume, with elastane mass taken from the factory's consumption figure of 3.10 g per pair.

IV. Results and Discussion

A. Where the losses originate

Elastane damage was confirmed as a persistent quality loss across the reviewed period, with overstretch and wavy welt the most frequent forms in the inspected rejects. The cause-and-effect analysis attributed 25% of all elastane damage to the feeding system, the largest single contributor, and the Pareto breakdown within that group identified yarn path behaviour as the dominant sub-cause at 44%. A parallel comparison of the two machine platforms in the facility points the same way. The modern Lonati SBYS machines, whose creel-to-feeder arrangement is balanced, recorded fewer elastane defects over 2025 than the conventional Soko machines. Within the Soko fleet, the machine with the longer yarn path carried the higher share of damage. These findings are consistent with geometry altering the tension carried by the elastane before loop formation, rather than with a material or operator effect. The prominence of elastane damage is itself consistent with Sadi et al. [8], who record elastane breakage among the small group of defect classes responsible for most faults in weft knitting. These findings motivated the trials that follow.

B. Effect of feeding angle on defect rate

Fig. 2 and Table II consolidate the three trials. At 50.2° the screening rate was 5.0%, against 1.0% at 45.0° and 1.5% at 38.7°. The design was sequential: levels whose effect was already resolved at the first stage were not carried forward. The disadvantage of 50.2° was unambiguous at 100 pairs, whereas the difference between 45.0° and 38.7° remained within the range attributable to sampling error. Experimental units were therefore reallocated to that comparison, which required a larger sample to resolve. The data establish 45° as the best of the angles tested rather than a verified optimum, since no angle between 45.0° and 50.2° was examined.

The design separates the angle effect from a possible machine effect. Trials 1 and 2 held machine identity constant, so no difference between machines can account for their result. Trial 3 ran the two angles over identical days, shifts and yarn lot, so no change over time can account for its result. The same angle performed better under both, four months apart, which leaves no single uncontrolled factor able to explain the outcome.

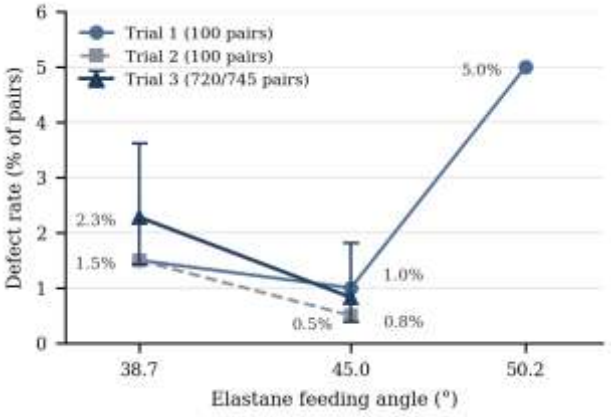


Figure 2. Elastane defect rate by feeding angle, all three trials. Error bars show 95% confidence intervals for Trial 3.

TABLE II. Trial results by feeding angle (Trial 1: 19–24 Jan; Trial 2: 29 Jan–3 Feb; Trial 3: 5–12 May 2026)

Trial	Angle (°)	Pairs	Defects (pairs)	Rate (%)	Stop (min)
1	45.0	100	1.0	1.0	1.5
1	50.2	100	5.0	5.0	10.0
1	38.7	100	1.5	1.5	3.1
2	45.0	100	0.5	0.5	1.0
2	38.7	100	1.5	1.5	3.1
3	45.0	720	6	0.83	10.0
3	38.7	745	17	2.28	25.0

C. Continuous production

In continuous production the 45.0° configuration recorded 6 elastane defects in 720 pairs (0.83%) against 17 in 745 pairs (2.28%) at 38.7°. The difference was statistically significant ($\chi^2 = 4.08$, df = 1, $p = 0.043$, Yates' correction), with a risk ratio of 2.74 (95% CI 1.09–6.91) for 38.7° relative to 45.0° and an absolute difference of 1.45 percentage points. On this evidence the null hypothesis of independence between feeding angle and defect incidence is rejected for the conditions tested. The interval is wide and its lower bound close to unity, so the data indicate an association of appreciable size without fixing its magnitude precisely. The test assumes that pairs fail independently. Defects may occur in clusters (within a yarn package or a shift, for example), in which case the p-value would understate the true uncertainty. Machine stop time followed the same ordering, 10 against 25 minutes.

D. Mechanism

Defect rate was higher at both the shallower and the steeper angle than at the benchmark, the minimum lying

between the tension rise at steep angles and the unstable delivery at shallow ones. Yarn tension was not measured during the trials, so the explanation that follows is an interpretation that fits the observations, not a mechanism this study demonstrates. The high-angle arm follows the capstan relation: a steeper approach raises delivered tension. Moving from 45.0° to 50.2° raises it by less than 3%, even at a guide friction coefficient of 0.3. A rise of that size cannot by itself produce a fivefold increase in defects, which suggests that 50.2° crossed a damage threshold that 45.0° did not. The low-angle arm reflects the second bound rather than tension magnitude, since 38.7° gives both the smaller deviation angle and the shortest free yarn length (12.81 cm against 14.14 cm); slack or unstable delivery at a shallow approach is the more plausible mechanism there. As tension was not instrumented, both explanations remain inferred rather than demonstrated; direct measurement at the feeder would distinguish them.

E. Waste-prevention potential

Table III sets out what elastane damage cost the facility in 2025. Across 351,042 pairs produced, 3,962 were lost to elastane damage, a rate of 1.13%. At 3.10 g of elastane per pair those garments carried 12.3 kg of elastane between them, worth about USD 122 at the factory's purchase price. That rate is an all-machine, all-style annual average and is not directly comparable with a single-style trial rate; treated as an achievable target rather than a measured outcome, the 0.83% recorded at 45.0° corresponds to roughly 1,040 pairs a year not discarded.

TABLE III. THE 2025 BASELINE: ELASTANE DAMAGE AT FACILITY LEVEL

2025 production and loss	Value
Pairs produced	351,042
Pairs lost to elastane damage	3,962
Elastane damage rate (%)	1.13
Elastane per pair (g)	3.10
Elastane in discarded pairs (kg)	12.3
Elastane price (USD/kg)	9.9
Value of discarded elastane (USD)	122

Because that projection rests on an assumed achievable rate, Table IV sets out the saving under several. The first row is 2025 as it stood: 3,962 pairs lost at 1.13%, the point every other row is measured against. The remaining rows apply lower rates to the same annual volume. At the trial rate, computed from the unrounded 6 defects in 720 pairs, the facility would lose 2,925 pairs and so avoid about 1,040; at 0.90% it would avoid about 800, and at 1.00% about 450. Which rate is reached does not change the ordering of the trial result, but it changes the size of the benefit considerably, so a facility adopting the setting should expect a figure within this range rather than the trial value itself. Partial adoption scales the same way: applying the setting to half the fleet halves the saving.

TABLE IV. ANNUAL SAVING UNDER DIFFERENT ACHIEVABLE DEFECT RATES

Defect rate (%)	Pairs lost per year	Fewer defective pairs than 2025	Elastane not discarded (kg/year)
1.13 (2025, actual)	3,962	–	–
0.83 (trial rate)	2,925	1,037	3.2
0.90	3,159	803	2.5
1.00	3,510	452	1.4

Read as a material saving, the result is trivial: of the 12.3 kg of elastane discarded in 2025, worth about USD 122, some 3.2 kg and USD 32 would be avoided. That framing, however, measures the wrong thing. Elastane damage is detected at final inspection, so what is lost is not 3.10 g of yarn but a finished garment, together with the ground yarn, dyeing, knitting, finishing, packaging and labour already invested in it. The meaningful unit is the 1,040 pairs, and the 3.2 kg is only the elastane fraction of their mass. Because elastane blends resist recycling [1], those garments are also unlikely to re-enter a material cycle; prevention is the only route that avoids the loss rather than deferring it.

The intervention itself carries no capital cost: changing the feeding angle means repositioning an existing yarn guide by a few centimetres, a setting that can be added to routine machine checks and verified with a steel rule. Measures of this kind suit small and medium manufacturers, for whom new machinery is rarely affordable and whose waste-reduction targets are increasingly set by buyers. Machine setting, normally treated as a productivity matter, is therefore also a waste-prevention instrument, and one currently unmeasured in most facilities.

This places the intervention at the top of the waste hierarchy. Manufacturing rejects are comparatively easy to address: they arise at a known machine, on a known day, in a facility that already counts them. The obstacle is attribution rather than measurement, since defect counts are treated as a quality metric and rarely enter environmental reporting. Recording elastane damage as avoided garment waste, alongside the quality figure it already is, would cost nothing and would make such interventions visible to buyers.

F. Practical implementation

Applying the result requires no measurement system that a hosiery factory does not already have. The setting rule is geometric: position the last guide so that its vertical drop to the feeder eyelet approximately equals the horizontal offset between them, which yields a balanced angle near 45°. Both distances are read with a steel rule while the machine is stationary, so the check takes under a minute per machine and can be added to the existing changeover and machine-setting routine rather than run as a separate audit.

Monitoring is equally undemanding, since elastane damage is already a coded defect in the factory's quality system. A facility adopting the setting can therefore

track its effect using records it collects anyway, comparing defect rates before and after the change by machine. What the present data cannot supply is the tolerance around the setting: how far the geometry may drift before the benefit is lost is unknown. Until a finer series of angles is tested, the practical recommendation is to re-establish the balanced condition locally for each machine type and yarn, rather than to transfer 45° as a fixed value.

G. Limitations

The trials covered a single machine model, yarn, speed and style in one factory, examined three angles only, and did not instrument yarn tension, so the findings are preliminary and specific to that environment. The annual projection assumes the trial rate is attainable across styles and machines, which these data cannot establish, and no claim is made that 45° is a universal optimum.

Three further qualifications bear on how much weight the result carries. First, the statistical test rests on the seven-day trial alone; the two screening runs are each too small for a defect count in single figures to be conclusive, and they are reported as supporting evidence rather than as replicates of equal weight. Second, the three trials do not share a single design, so the comparison across them is qualitative: what they share is the ordering of the angles, not a common experimental structure. Third, the mechanism advanced here is inferred from geometry and defect counts rather than measured, so while the two-sided account is consistent with the observations, an alternative explanation acting on both extremes cannot be excluded without tension data at the feeder.

None of these qualifications affects the practical recommendation, which is conservative: adopt a balanced geometry, verify it locally, and monitor the existing defect code. They do affect how far the quantitative estimate should travel, and the figures in Table IV should be read as the range within which a facility might reasonably expect to land rather than as a predicted outcome.

V. CONCLUSION

Within the conditions tested, elastane feeding angle was associated with the incidence of elastane damage in single-cylinder tights knitting. The balanced 45.0° configuration gave the lowest defect rate and the least stop time of the three angles examined, its difference from 38.7° being consistent across all three trials and statistically significant in continuous production. Applied to a full year of production, the difference corresponds to approximately 1,040 finished garments not discarded, achieved by repositioning a single yarn guide at no capital cost. These findings hold for the machine model, yarn, speed and style tested in one facility. No claim is made that 45° is a universal optimum: it is the best of three angles examined, and the geometry should be re-established locally for other machines and yarns.

The contribution of this work to circular practice is not the mass of material recovered, which is small, but the point of intervention. Waste that is prevented before a garment is completed never enters a recycling stream that, for elastane blends, barely exists. Process geometry is therefore worth treating as a first-order waste-prevention measure in apparel manufacturing, alongside the material substitution and end-of-life strategies that dominate current practice. Further work should instrument YIT at the feeder, examine a finer series of angles around 45°, and extend to a factorial design across machines, styles, elastane linear density and speed.

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REFERENCES

[1] M. Zhu, C. Gao, S. Wang, S. Shi, M. Zhang, and Q. Su, "Recycling of spandex: Broadening the way for a complete cycle of textile waste," Sustainability, vol. 17, no. 8, art. 3319, 2025.

[2] T. Jovanović, Ž. Penava, and Z. Vrljičak, "Impact of the elastane percentage on the elastic properties of knitted fabrics under cyclic loading," Materials, vol. 15, no. 19, art. 6512, 2022.

[3] X. Gao, L. Wang, and X. Hao, "An improved Capstan equation including power-law friction and bending rigidity for high performance yarn," Mechanism and Machine Theory, vol. 90, pp. 84–94, 2015.

[4] F. B. Vasconcelos, J. P. P. Marcicano, and R. A. Sanches, "Influence of yarn tension variations before the positive feed on the characteristics of knitted fabrics," Textile Research Journal, vol. 85, no. 17, pp. 1864–1871, 2015.

[5] W. Iqbal, Y. Jiang, Y.-X. Qi, and L. Xu, "Yarn damage evaluation in the flat knitting process," Autex Research Journal, vol. 21, pp. 272–283, 2020.

[6] A. K. M. M. Hossain and M. I. Islam, "Mathematical modeling of dynamic yarn input tension on circular weft knitting machine with positive storage feeding," The Journal of the Textile Institute, vol. 116, no. 1, 2025.

[7] M. A. Taher, M. M. Rahman, M. A. Jahangir, M. S. Mia, and Ashaduzzaman, "Study on different types of knitting faults, causes and remedies," International Journal of Textile Science, vol. 5, no. 6, pp. 119–131, 2016.

[8] M. S. Sadi, N. Nahar, M. S. Hossain, and S. H. Sajib, "Amendment of finished knitted fabric quality by reducing the intensity of defects and improvement techniques," American Journal of Materials Science, vol. 8, no. 1, pp. 6–14, 2018.

[9] S. Abrishami, A. Shirali, N. Sharples, G. E. Kartal, L. Macintyre, and O. Doustdar, "Textile recycling and recovery: An eco-friendly perspective on textile and garment industries challenges," Textile Research Journal, vol. 94, no. 23–24, pp. 2815–2834, 2024.

[10] U. N. Haq and S. M. R. Alam, "Implementing circular economy principles in the apparel production process: Reusing pre-consumer waste for sustainability of environment and economy," Cleaner Waste Systems, vol. 6, art. 100108, 2023.

[11] European Commission, "EU Strategy for Sustainable and Circular Textiles," COM(2022) 141 final, Brussels, 30 Mar. 2022.