Material-Sensitive Carding of Mechanically Recycled Cotton

Interaction Effects and Process Windows for rCO Blends

Bettina Cherdron[1,2] · **Piyumanthi D. Nissanka**[3] · **Prof. Dr.-Ing. Stefan Schlichter**[2] · **Prof. Dr.-Ing. Mesut Cetin**[1,2]

[1] ITA Augsburg gGmbH · Recycling Atelier Augsburg [2] Technische Hochschule Augsburg [3] Ghent University · Erasmus Mundus WE-TEAM

1 rCO is a different material, not lower-grade cotton

Post-industrial 100 % cotton knit waste was mechanically recycled and compared with virgin cotton (Uster AFIS Pro 2). rCO shows different material behaviour and imposes additional demands on carding:

- Shorter and broader fibre length distributions
- Higher short fibre and nep content
- Fibre bundles and varying degrees of opening

Opening, cleaning and homogenisation must be achieved **without further fibre damage or nep formation**.



Virgin cotton



Mechanically recycled cotton (rCO)

Raw material (AFIS)	Virgin	rCO
SFC(n) < 12.7 mm / %	28.9	53.9
Mean length L(n) / mm	19.7	12.6
UQL(w) / mm	32.5	22.9
Total neps / (1/g)	61	1 549
Trash / (1/g)	14	75



RESEARCH QUESTION

Can one common carding setting serve blends with different rCO contents – or do favourable conditions shift with rCO content?

2 Materials & methods

Blends · virgin cotton + rCO from post-industrial knit waste, opened and mixed (DILO Temafa), cleaned (Trützschler CL-U)

30 % rCO **50 % rCO** **70 % rCO**



Trützschler TC 11

Carding · TC 11, Recycling Atelier Augsburg, 5 ktex sliver

Full factorial design · 3 × 3 × 2 × 3 = 54 trials + 5 replicates = **59 carded slivers**

Card-to-flat setting 0.1 · 0.2 · 0.3 mm

Cylinder speed 350 · 450 rpm

Flat speed 150 · 250 · 350 mm/min

Responses · Uster AFIS Pro 2: SFC(n), L(n), UQL(w), total nep count · Uster Tester 6: sliver mass variation CVm %

Statistics · overall and blend-wise ANOVA (α = 0.05, Minitab) incl. two-factor interactions; weighted Sliver Quality Score for multi-response optimisation

3 Results

A · rCO content sets the achievable quality level

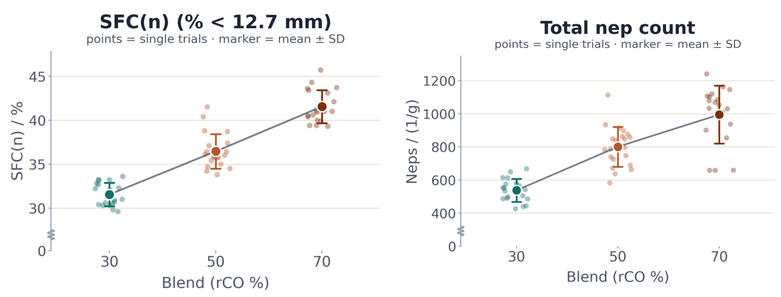


Fig. A · Faint points = single trials, marker = mean ± SD (n = 19–21 per blend). Blend ratio is the dominant factor for fibre-length responses and neps (SFC(n): F = 349, L(n): F = 385, p < 0.001). L(n) falls from 18.2 to 15.5 mm, UQL(w) from 30.6 to 27.2 mm; CVm rises from 3.7 to 4.3 %.

B · Cylinder-to-flat setting is the key machine parameter – and acts blend-dependently

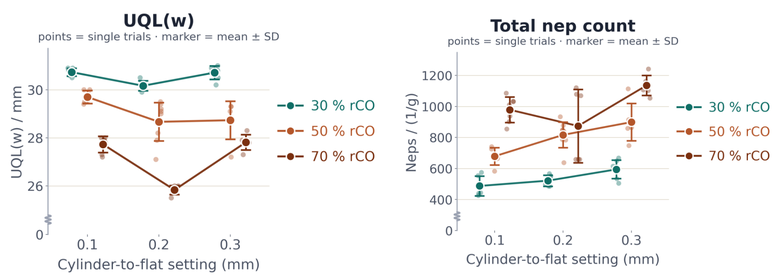


Fig. B · Faint points = single trials, marker = mean ± SD (n = 6–9 per cell). The intermediate 0.2 mm setting is least favourable for fibre length in all blends. Neps are lowest at 0.1 mm for 30 % and 50 % rCO, but at 0.2 mm for 70 % rCO – a close gap improves opening, yet high rCO content tolerates less aggressive action.

C · Cylinder speed is a quality compromise

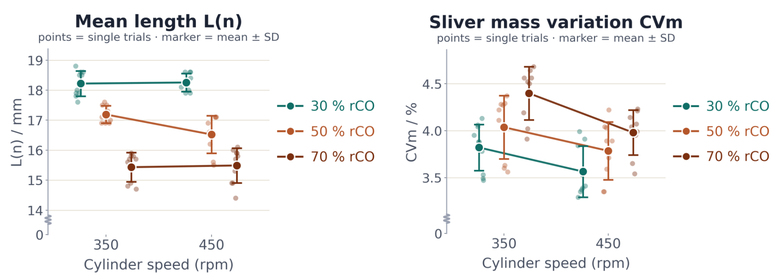


Fig. C · Faint points = single trials, marker = mean ± SD (n = 9–10 per cell; CVm without the outlier trial 18). 450 rpm improves sliver evenness in every blend, but reduces mean fibre length at 50 % rCO and raises neps at 70 % rCO. Flat speed is the least influential factor within the tested range.

D · Nep reduction and fibre preservation call for different settings – increasingly so with rCO content

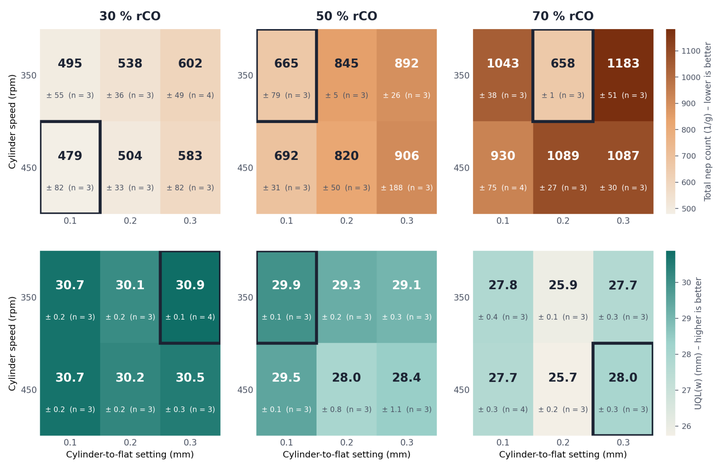


Fig. D · Measured total nep count (top) and upper-quartile length UQL(w) (bottom) over the setting × cylinder speed grid, all 59 trials; cell = mean ± SD over the three flat speeds, frame = best cell. 30 % rCO: flat field, the setting hardly matters. 50 % rCO: both targets agree on 0.1 mm / 350 rpm. 70 % rCO: the targets conflict – neps are lowest at 0.2 mm, where UQL(w) is poorest; fibre length needs 0.1 or 0.3 mm. The favourable window is a blend-specific compromise, not a universal optimum.

4 Process windows per blend

Best observed conditions from the weighted Sliver Quality Score (SFC(n) 0.28 · UQL(w) 0.25 · neps 0.22 · CVm 0.15 · L(n) 0.10) within the tested range:

Blend	Setting / mm	Cylinder / rpm	Flat / mm·min^{-1}
30 % rCO	0.1	350	350
50 % rCO	0.1	350	150
70 % rCO	0.3	450	250

Quadratic response-surface models: significant for 50 % (R^2 = 0.84, p = 0.008) and 70 % rCO (R^2 = 0.83, p = 0.005); not significant for 30 % rCO. Centre-point repeatability (n = 3): CV 2.7–4.2 % for length responses, 8.2 % for CVm, 18.9 % for neps.

5 Key findings

1 **Material composition dominates.** Rising rCO content increases SFC(n), neps and CVm and reduces L(n) and UQL(w).

2 **Machine effects are not universal.** The cylinder-to-flat setting acts non-linearly and interacts with rCO content – the same gap does not act the same way in every blend.

3 **No common optimum.** At 70 % rCO nep reduction and fibre preservation demand different settings; favourable windows are a blend-specific balance of opening intensity, fibre preservation, nep reduction and sliver evenness.



ANSWER TO THE RESEARCH QUESTION

Yes – favourable carding conditions shift with rCO content. Carding settings should be selected per blend.

6 Outlook

- **Ring spinning** of the optimised slivers – yarn strength, evenness, imperfections, hairiness
- **Nep removal efficiency** from input vs. output nep levels; length distribution of flat strips and card waste
- **Carding index** linking material quality, process parameters and sliver quality

Contribution: systematic, data-supported process design for mechanical textile recycling.

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Institut für Textiltechnik Augsburg gGmbH
Am Technologiezentrum 5
86159 Augsburg

www.tha.de www.ita-augsburg.com