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Fibre length distribution measurement of reclaimed carbon fibres to assess chopping procedures

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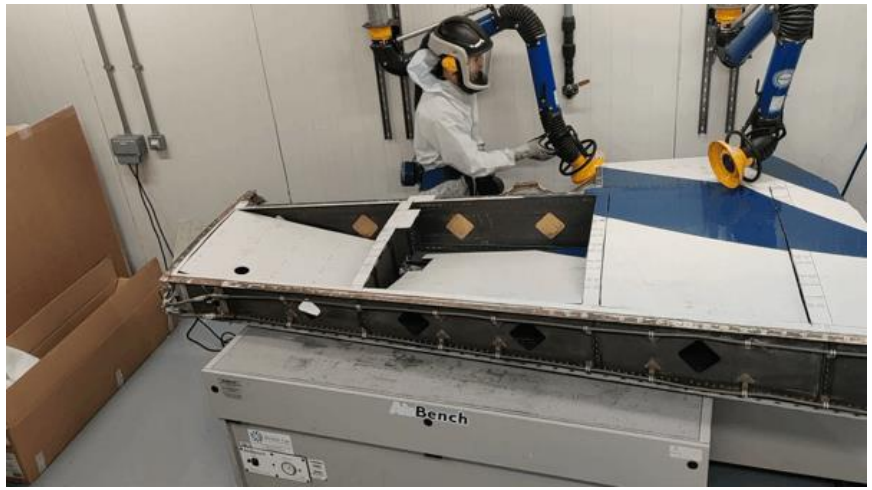
How can we enable a supply chain to recycle end-of-life composite components?

How do we encourage industry to use recycled composite materials?

What does composite recycling look like?

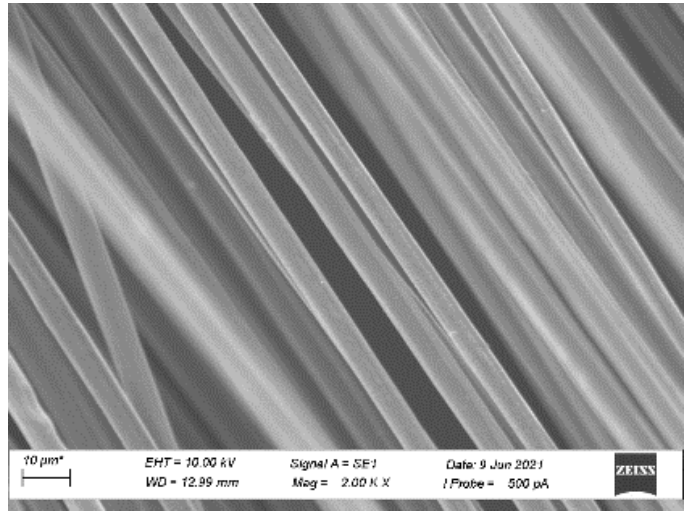
Context

Extracted ≈50% weight of two A320 VTPs as CFRP panels



Context

Panels shredded and fibres reclaimed using pyrolysis



Context

Produced new discontinuous fibre format materials

Bulk moulding compound (BMC)

- *20% fibre content*
- *Fibre length 12 mm*
- *Randomly aligned*

Non-woven fabric

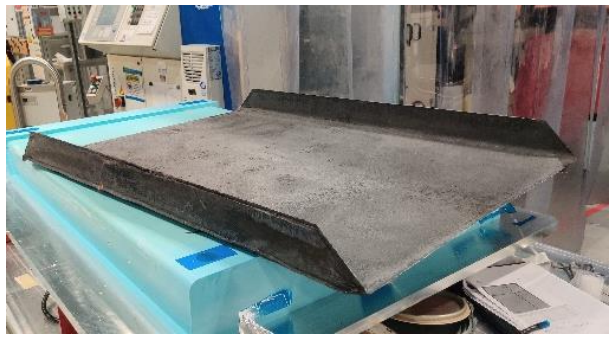
- *Up to 30% fibre volume fraction*
- *Fibre length 80 mm*
- *Some alignment*

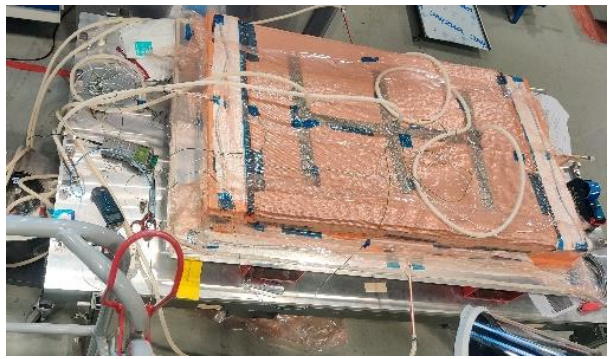
HiPerDiF highly aligned tape

- *Up to 50% fibre volume fraction*
- *Fibre length 3 - 12 mm*
- *High alignment*

Context

Manufactured a second life component using rCF materials





Wheelchair ramp manufactured by vacuum infusion of carded nonwoven rCF fabric with Arkema Elium, FVF = 13%

Why is fibre length control an issue?

Methodology

	Sample	Original Fibre Length	Chopping Technique	Target Length
Run 1: Short rCF + manual cut	rCF(p)	l_0 = 80mm	Rotary	4mm
Run 2: Short rCF + semi-automatic cut	rCF(p)	l_0 = 80mm	Depositor	4.5mm
Run 3: Long rCF + semi-automatic cut	rCF(s)	l_0 = 950mm	Depositor	4.5mm
Run 4: Long vCF + semi-automatic cut	vCF	l_0 = 950mm	Depositor	4.5mm

80 mm long pyrolyzed fibres, rCF(p)

950 mm long steam-pyrolyzed fibres, rCF(s)

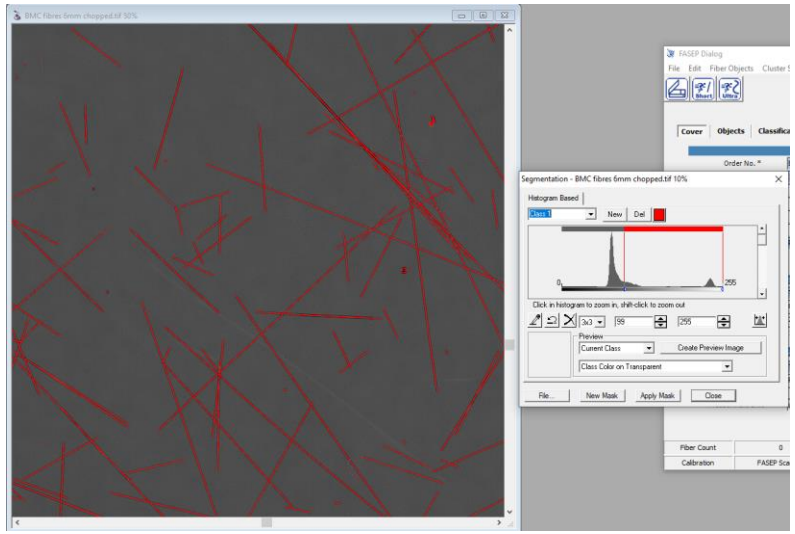
Depositor chopping method

- Model GRC6000rpm pneumatic motor-powered glass fibre depositor
- Cutting cylinder with 24 slots for steel blades at an angular resolution of 15°
- Output lengths limited to multiples of 4.5 mm
- Semi-automatic process due to manual feeding

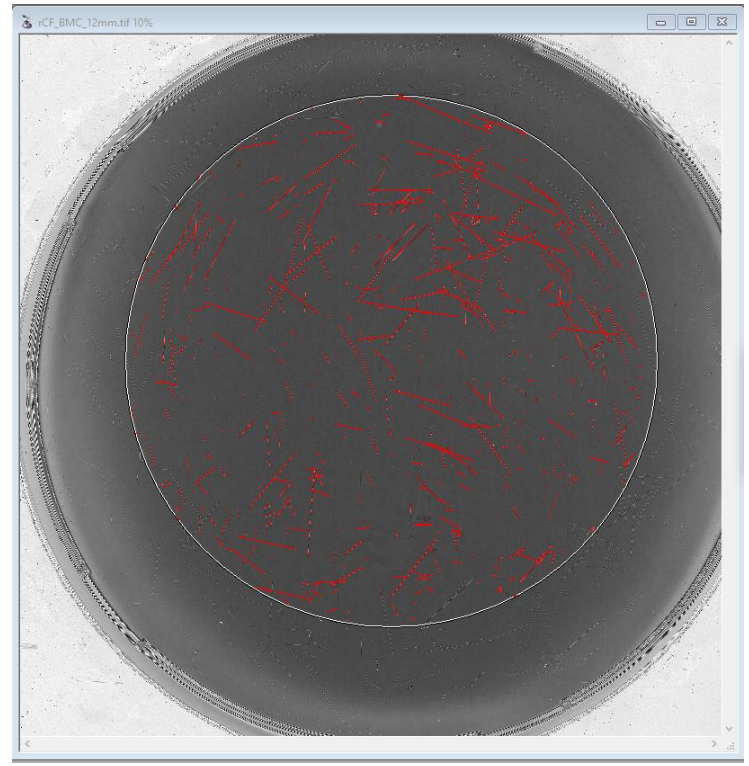
Methodology

Fibre length distribution measurement method

- FASEP 3E Eco partially automated system used previously for glass fibres[1][2] and natural fibres
- Fibre samples dispersed in water and diluted to a concentration level of 20 to 40 mg per litre
- 4800dpi resolution scan taken of fibre sample before image analysis method used to determine fibre length distribution
- Objects in the image categorised and excluded based on a minimum width criteria
- Clusters interpreted using Hough transform



Defining objects in the scan



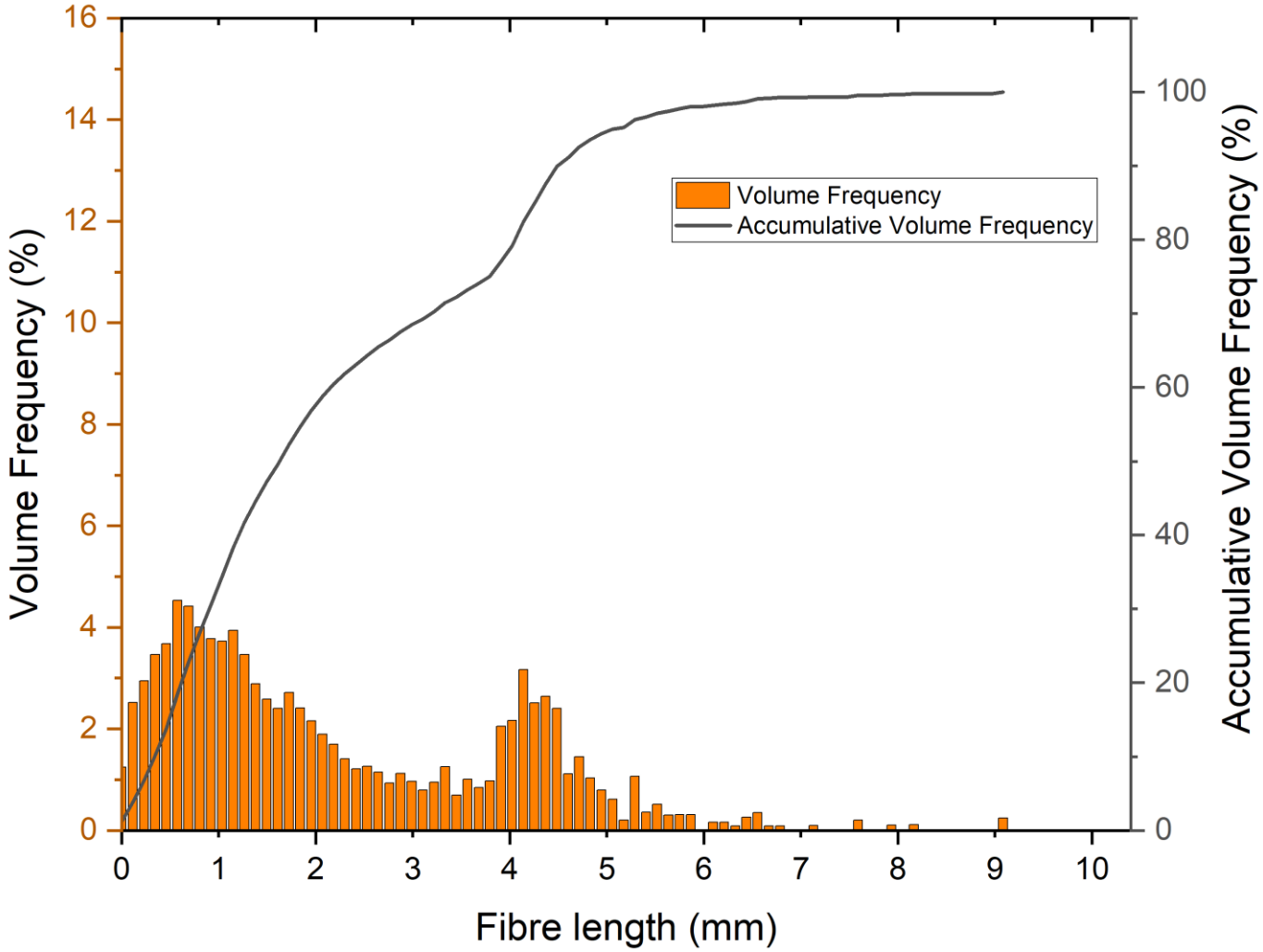
Defining the area for analysis

[1] FASEP ultra-automated analysis of fibre length distribution in glass-fibre-reinforced products. *Hartwich et al*. Proceedings of SPIE 7389 Optical Measurement Systems for Industrial Inspection VI; 7389(21). 17 June 2009.

[2] Effects of thermal recycling temperatures on the reinforcement potential of glass fibers. *Nagel et al.* Polymer Composites; 39(4): 1032-1040. 2018.

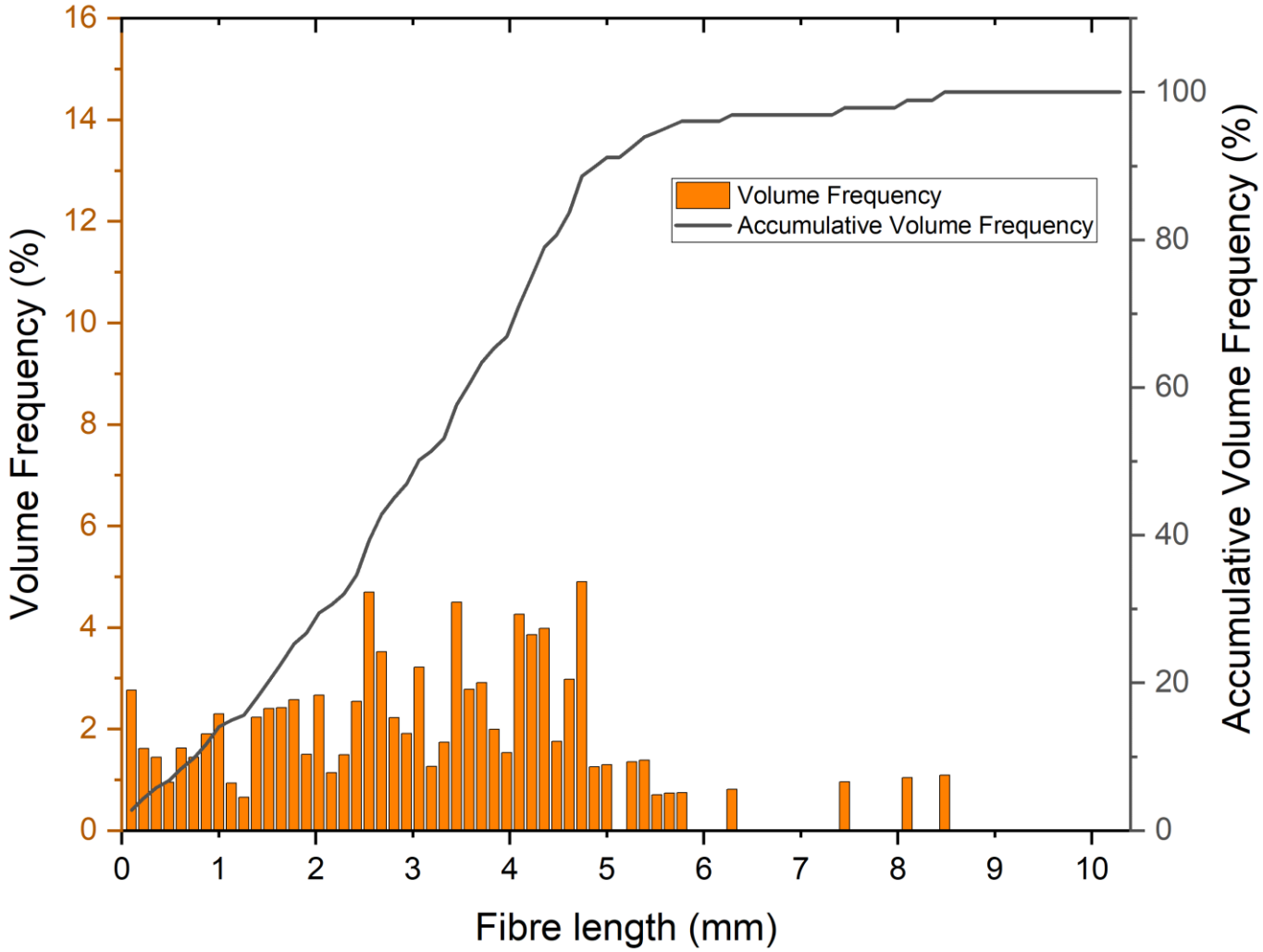
Results

Hand chopping
L = 80 mm
Pyrolysed fibre



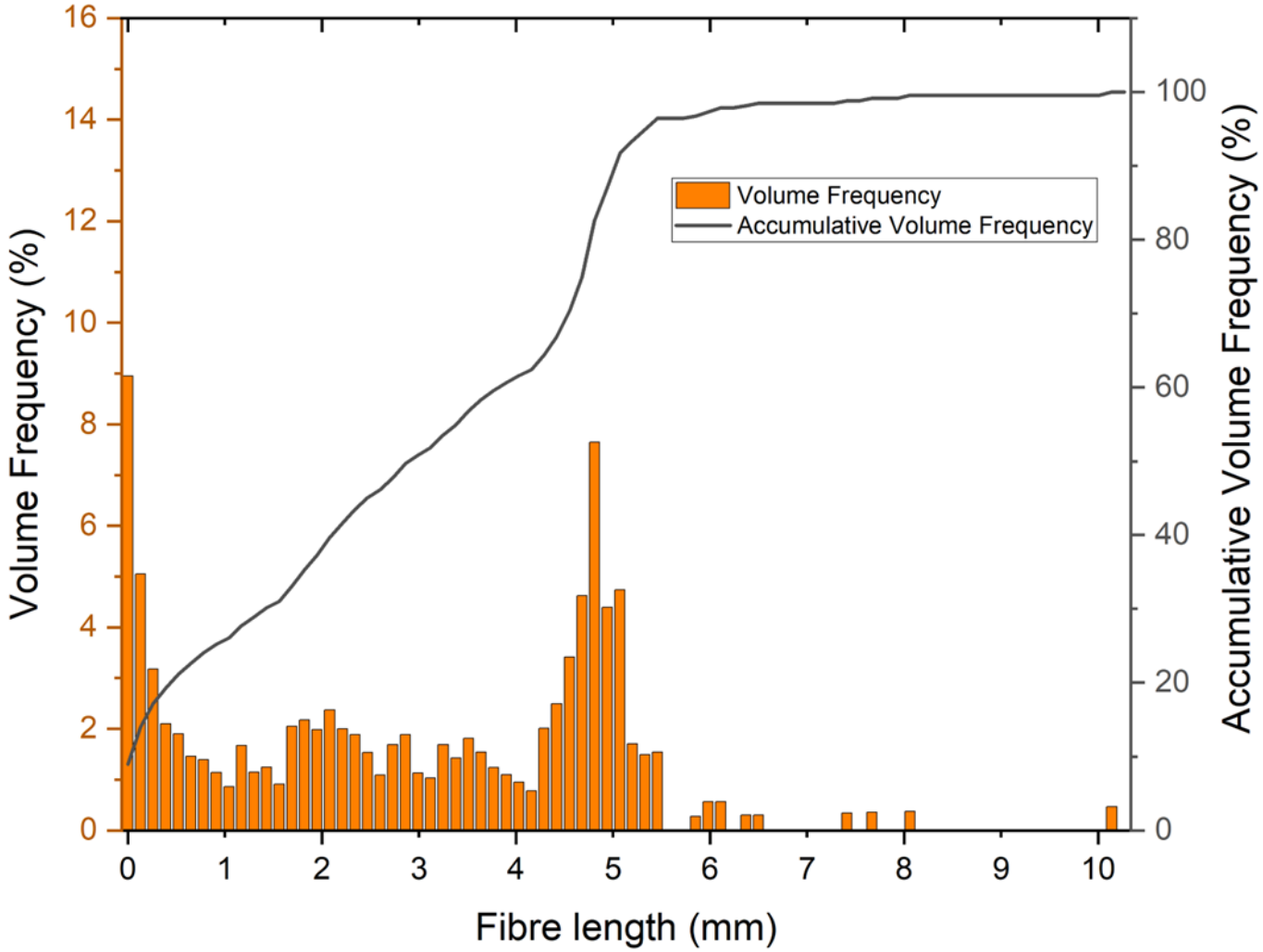
Results

Semi-automatic
L = 80 mm
Pyrolysed fibre



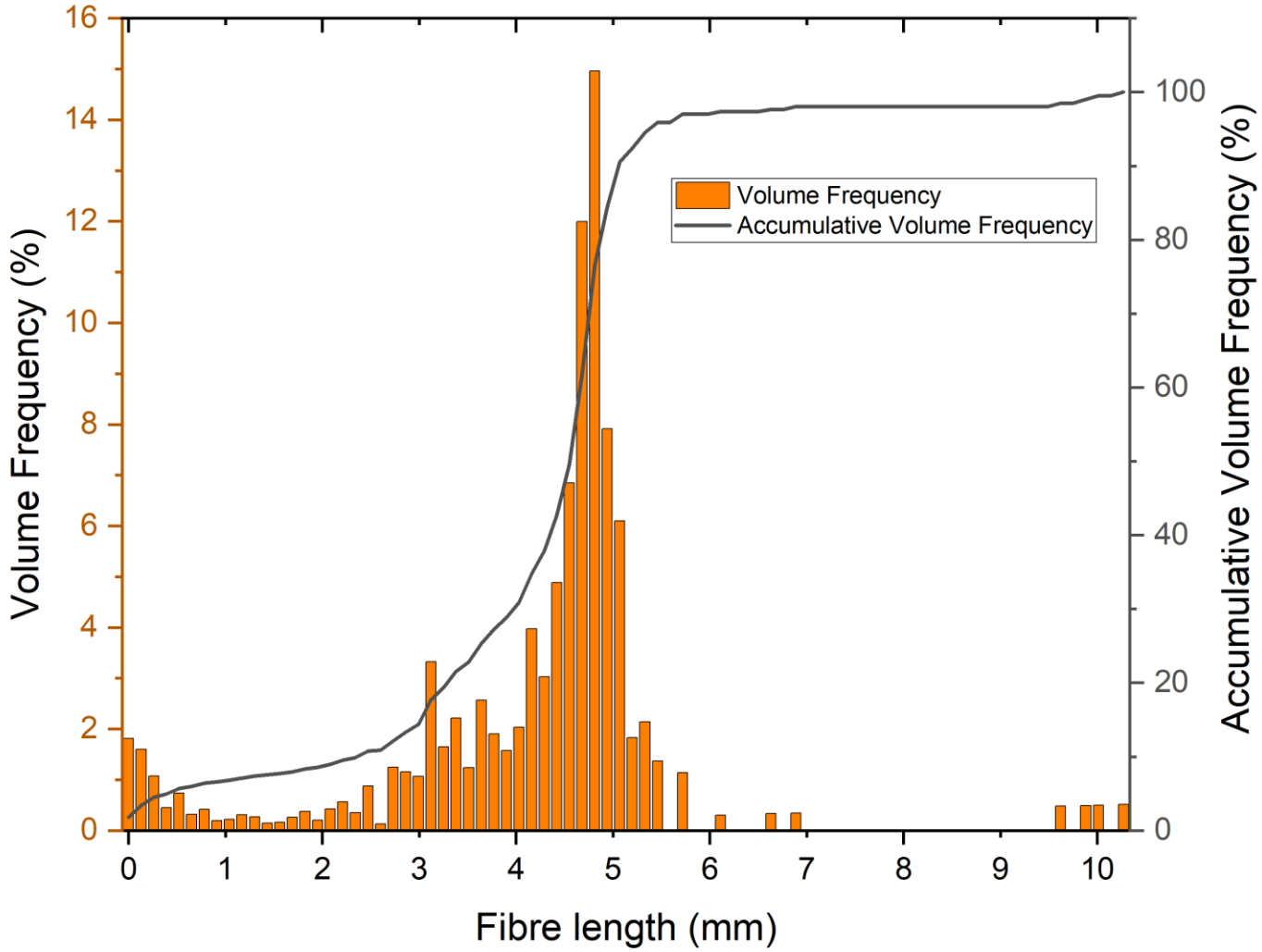
Results

Semi-automatic
L = 950 mm
Steam-pyrolysed fibre



Results

Semi-automatic
L = 950 mm
Virgin fibre

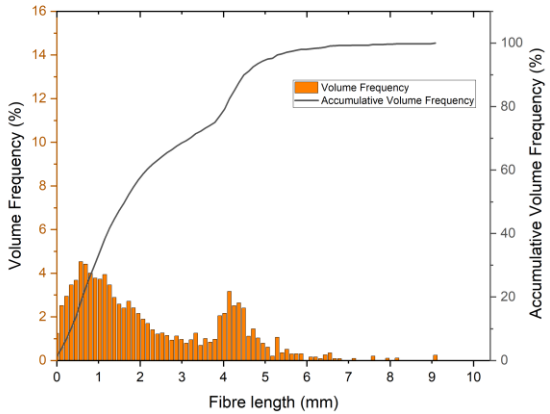


Results

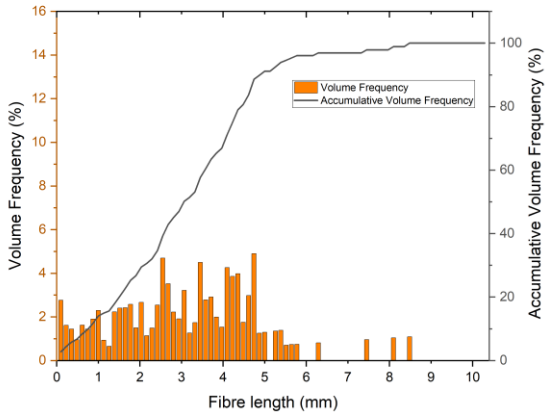
	Target Length (mm)	Median fibre length (mm)	Target length ± 25%	Mode ~4mm (mm)	±0.5 mm of mode ~4mm
Run 1: Short rCF + manual cut	4.0	1.74	27%	4.20	18%
Run 2: Short rCF + semi-automatic cut	4.5	3.19	42%	4.80	20%
Run 3: Long rCF + semi-automatic cut	4.5	3.00	42%	4.81	31%
Run 4: Long vCF + semi-automatic cut	4.5	3.31	73%	4.73	58%

- Significantly higher frequency of shorter fibres in the reclaimed samples for all chopping methods
- Longer original fibre length improves precision when using the depositor
- Chopping virgin fibre using the depositor is more precise and accurate than reclaimed fibre

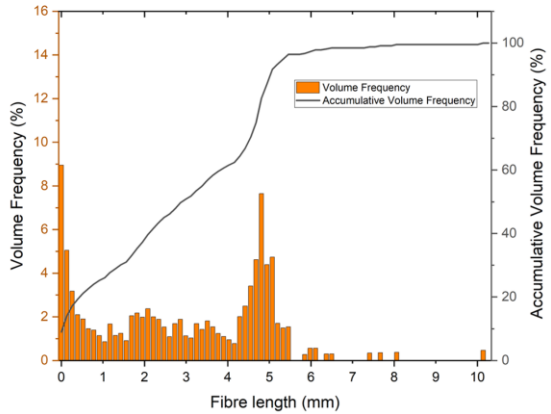
Hand chopping, rCF, L_0 = 80mm



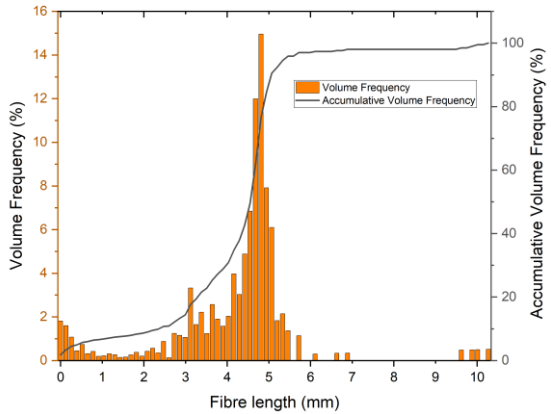
Depositor, rCF, L_0 = 80mm



Depositor, rCF, L_0 = 950mm

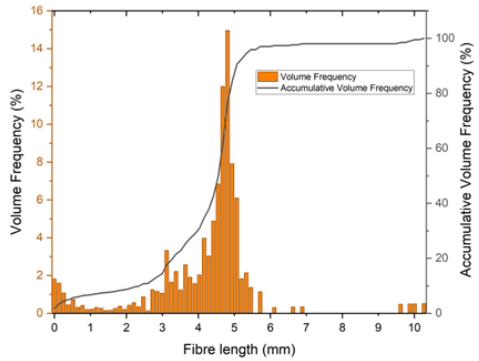


Depositor, vCF, L_0 = 950mm



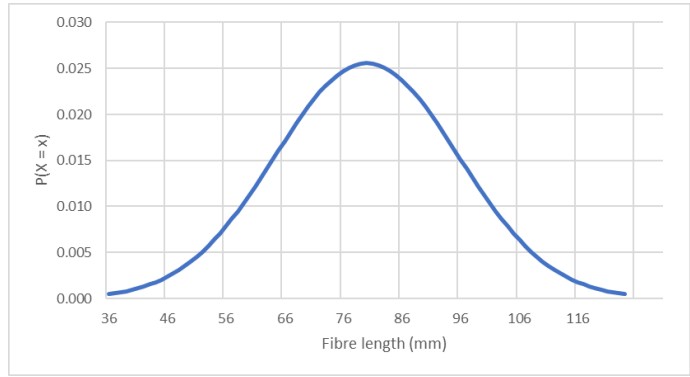
Impact

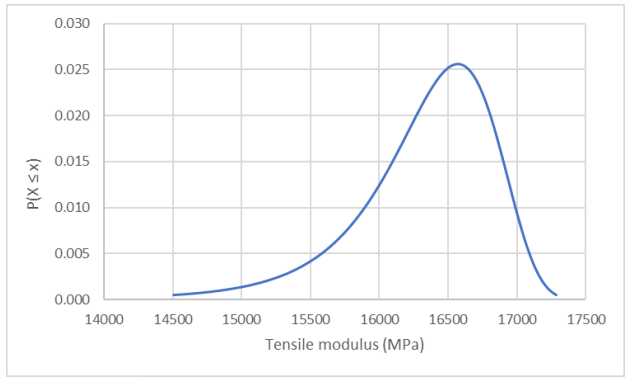
- The chopping of reclaimed fibre is unlikely to produce a single value result.
- By having a robust method for measuring fibre length distribution, discontinuous reclaimed carbon fibre materials can be characterised including fibre length variability.
- Recycled carbon fibre components can be designed with more confidence and predictive models can be applied.



Fibre length distribution measurement

Representative mathematical model





Predictive model for stiffness and strength

Acknowledgements

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