AN INVESTIGATION INTO FLAT GLASS FIBRES FOR INJECTION MOULDED POLYAMIDE 6,6 COMPOSITES

University of Strathclyde Engineering

Andrew T. Carlin, James L. Thomason, Liu Yang

Advanced Composites Group, Mechanical & Aerospace Engineering, University of Strathclyde, Glasgow, a.carlin@strath.ac.uk

1. Background

- Glass fibres (GFs) account for over 90% of reinforcement fibres used in fibre-reinforced composites
- Innovation is required in glass reinforced thermoplastics to support the transition to low-carbon vehicle platforms
- Flat glass fibres (FGFs) developed to improve mechanical & physical properties in injection moulded parts
- Flat glass fibres are fibres with a 'flattened elliptical' cross-section
- Composite property improvement thought to be related to reported increased in residual FGF length
- Very little academic literature to support industrial uptake
- In depth study required to correlate differences in fibre properties to composite microstructure and properties

2. Fibre geometry characterisation

- The cross-sectional area (CSA) of FGFs was characterised & compared against circular fibres of same composition
- Established that accurate characterisation of FGF CSA only possible using Scanning Electron Microscopy (SEM)
- Attempts to measure FGF CSA from less resource intensive optical microscopy were unsuccessful
- With optical microscopy significant edge effects observed; SEM has higher magnification and minimal edge effects
- Significant difference in tensile properties found depending on CSA observation method used:

	Optical transverse diameter	Optical cross-sectioned	SEM cross-sectioned
Mean Cross Sectional Area (μm^2)	145 ± 6	134 ± 9	143 ± 7
Mean Fibre Tensile Strength (MPa)	2080 ± 100	2315 ± 158	2345 ± 174

Table 1: Mean CSA and tensile strength of unsized, circular fibres, 20mm gauge length, with CSA measured by different methods , 95% confidence interval error.

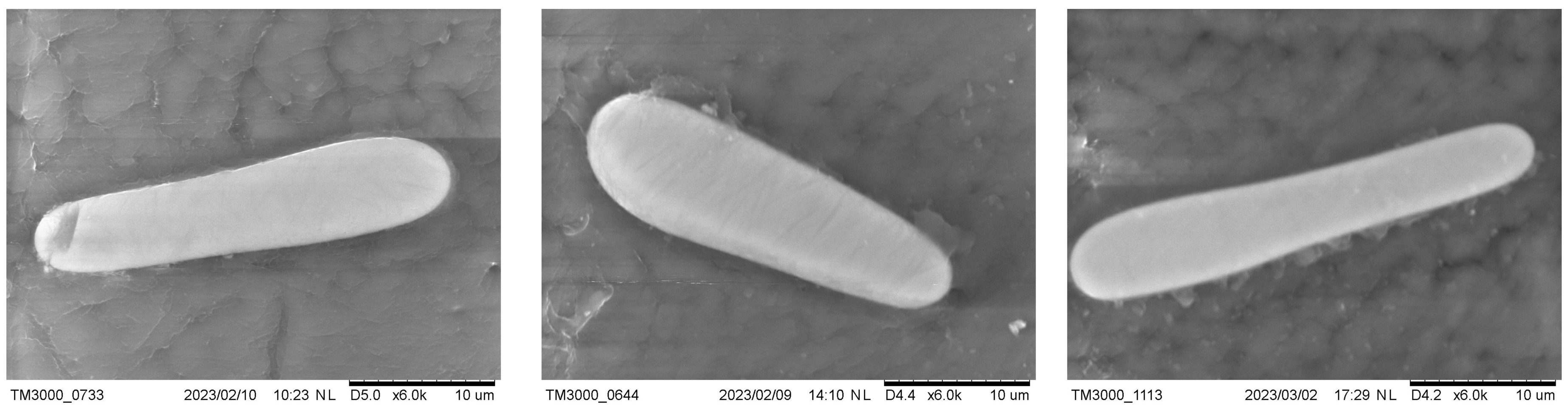

Figure 1: SEM mages of flat glass fibres, highlighting the sometimes-skewed nature of the observed cross-section .

- Observed that FGF shape is not always 'perfectly flat'; many fibres show skewed cross-sections

3. Fibre tensile properties

- Tensile strength characterised at 20mm, 40mm and 80mm gauge lengths
- Sized flat glass fibres found to be significantly stronger than circular sized fibres (CGFs); PA compatible sizing
- No significant difference overserved between unsized flat and circular fibres

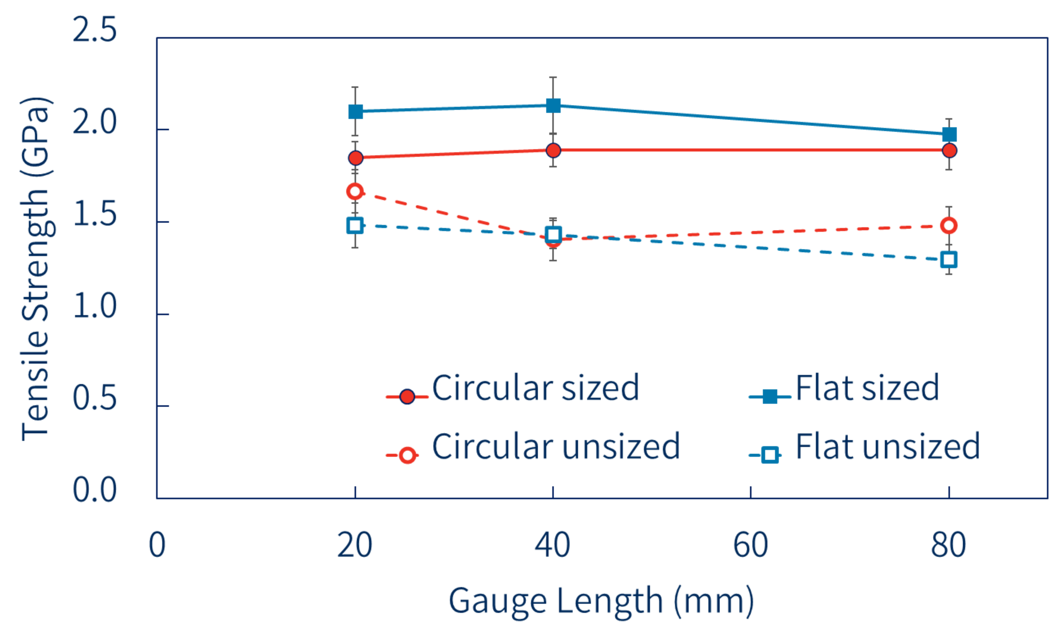

Figure 2: Tensile strength of flat and circular, unsized and sized fibres, at 20 mm, 40 mm and 80 mm gauge length, with 95% confidence interval error bars

- Differences in failure behaviour noted for flat and circular fibres across different gauge lengths; FGFs shatter less

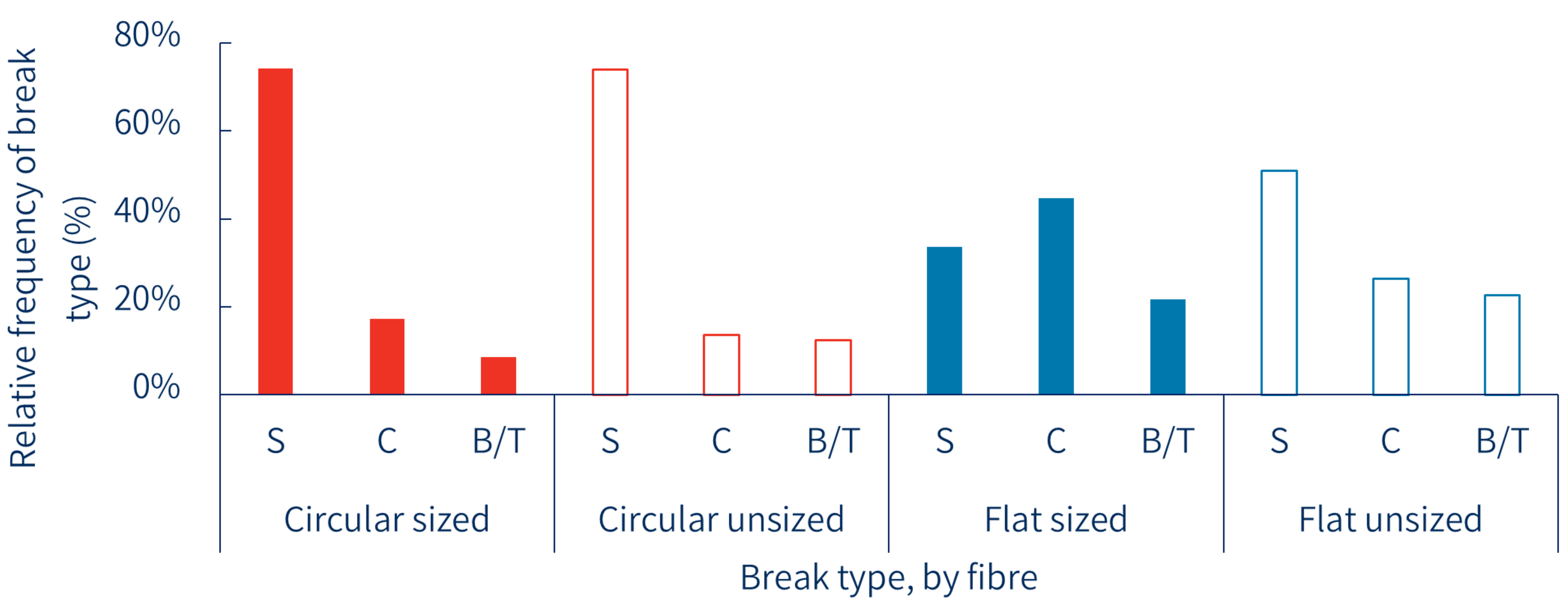

Figure 3: Failure behaviour of circular and flat, sized and unsized fibres, at 20 mm gauge length, where: S, denotates shattered fibres; C, fibres which broke cleanly with remains; B/T, fibres which broke cleanly with remains near the end tabs.

- Fractography observations show the different types of failure behaviour of flat glass fibres

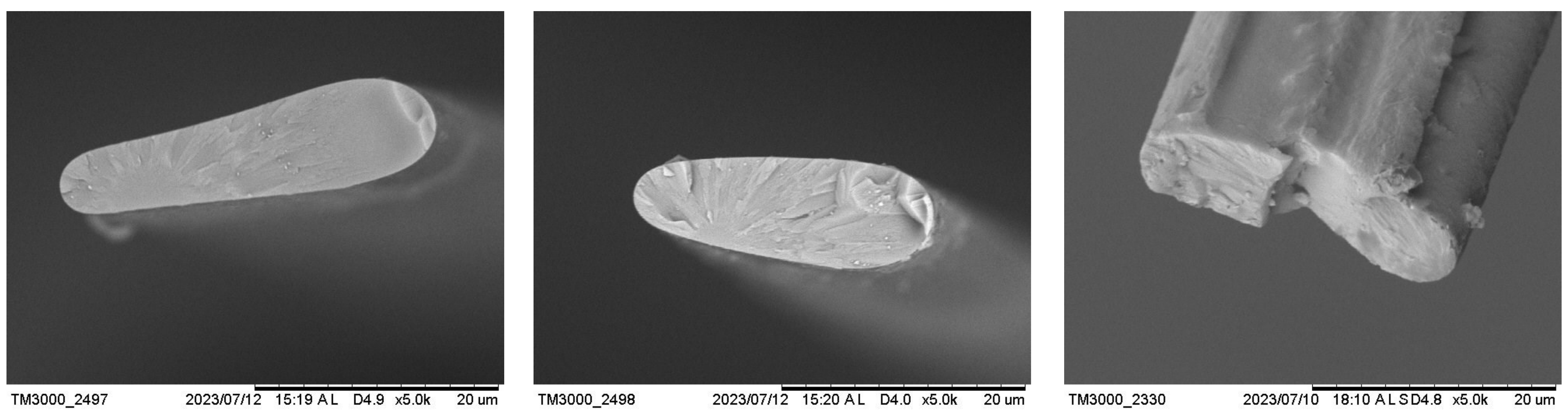

Figure 4: Fractography analysis using SEM showing different fracture surfaces of glass fibres after tensile testing

4. Composite fibre length analysis

- Fibre length degradation occurs throughout the compounding and injection moulding process
- Tensile strength is directly correlated to the residual fibre length of injection moulded composites

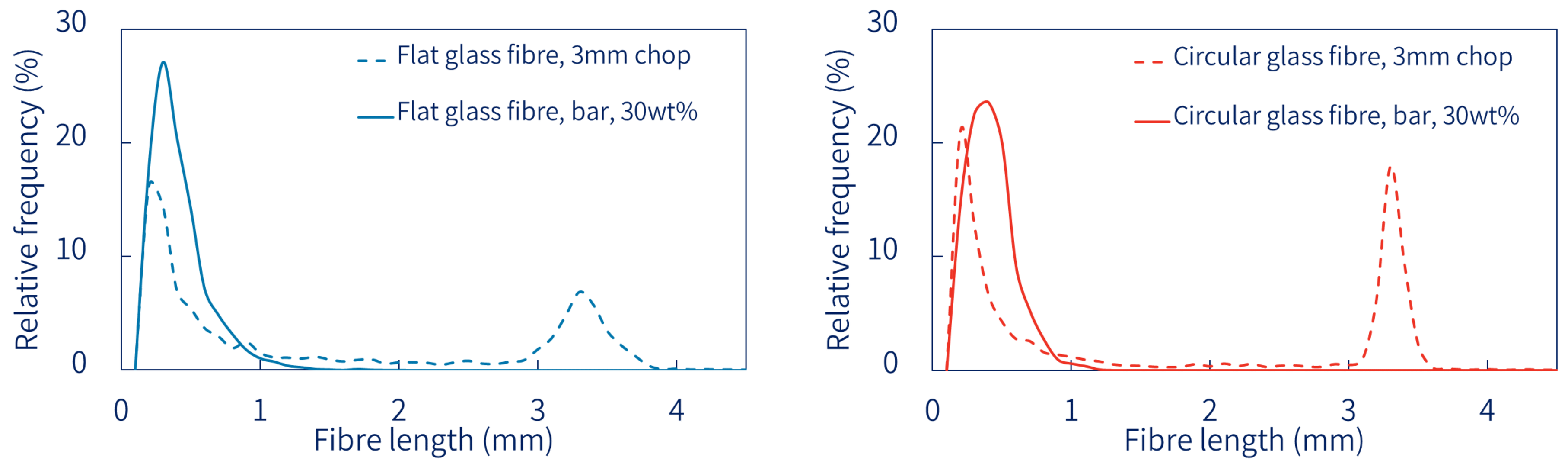

Figure 5: Fibre length distributions for virgin input chop and residual fibre length in composite (PA6,6) bars with 30wt% fibre, circular fibres left, flat fibres right.

- Residual fibre length found to be greater in flat glass fibre reinforced polyamide 6,6 (PA6,6) than circular fibre

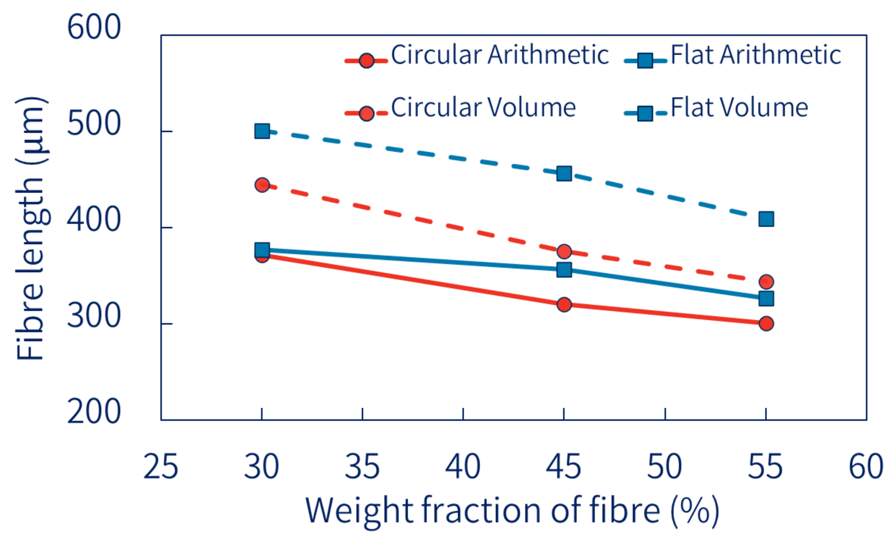

Figure 6: Arithmetic and volume mean residual fibre length of circular and flat fibre reinforced polyamide 6,6, composites.

- Data supports hypothesis that lower fibre second moment of area leads to less fibre breakage during processing

5. Composite tensile properties

- Tensile properties assessed in PA6,6 reinforced glass of varying glass weight contents: 30-55 wt%
- Use of FGF only have significant improvement on properties at high weight fractions when dry as moulded (DaM)

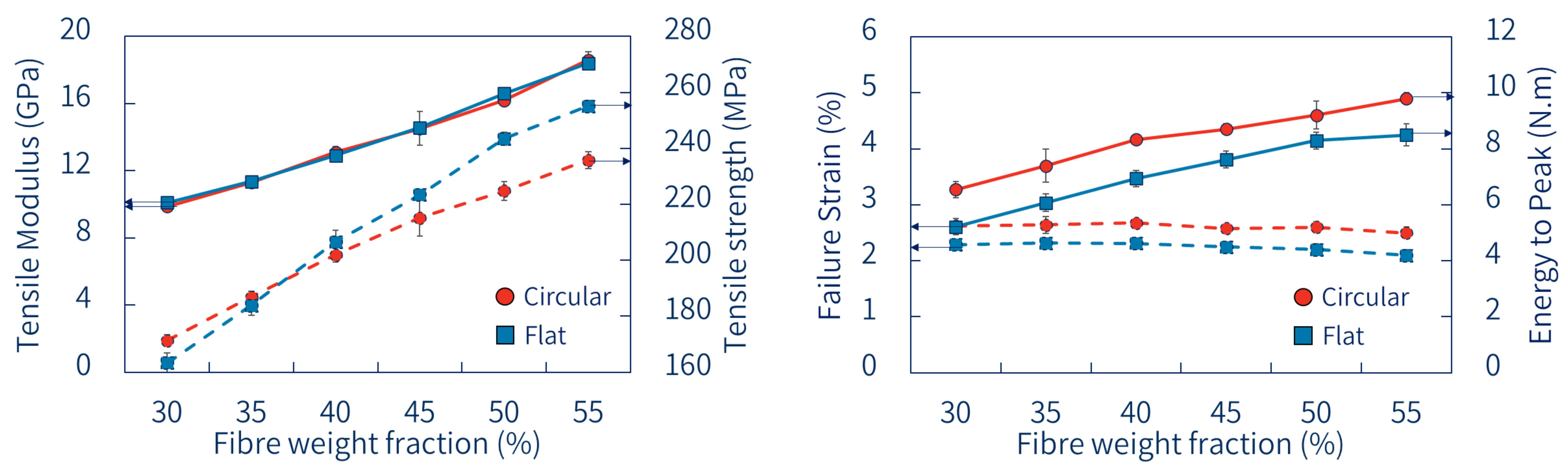

Figure 7: Tensile strength and modulus (left), and Energy to yield and Failure strain (right), of unconditioned (DaM) flat and circular reinforced polyamide 6,6, at 30-55wt% fibre content, with 95% confidence interval error bars.

- After 24 h conditioning in a water bath at 100°C (and subsequently tested at room temperature), FGF have a significant influence on room temperature tensile properties

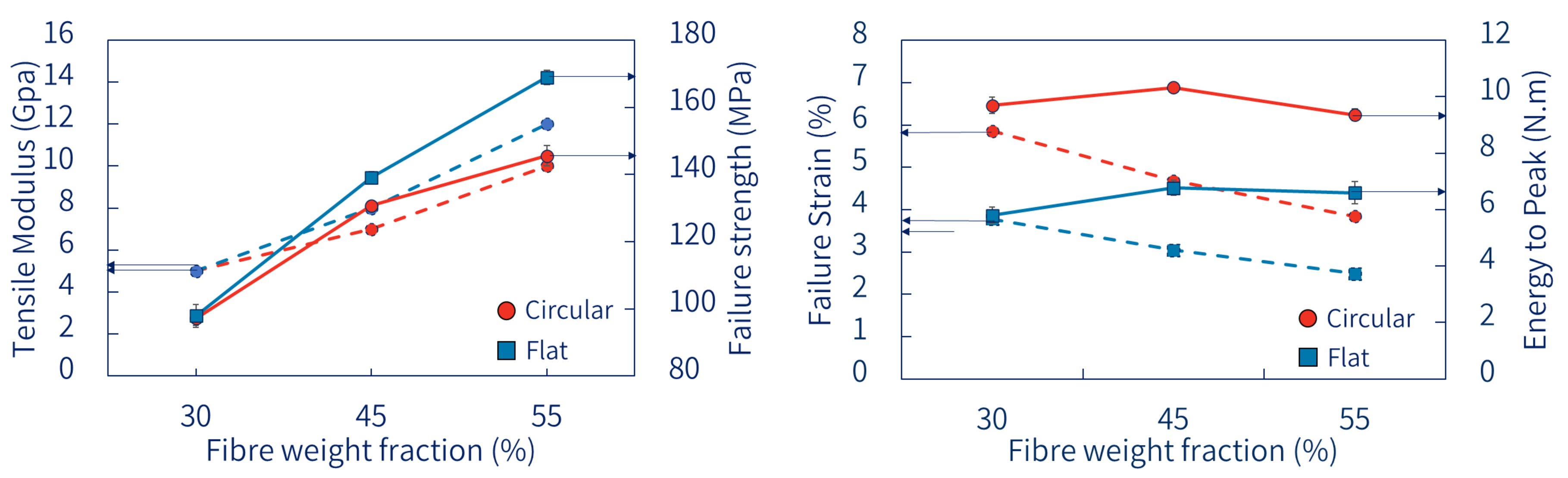

Figure 8: Failure strain and Failure strength (left), and Energy to yield and tensile modulus (right), of conditioned (24 h boiling water) flat and circular reinforced polyamide 6,6, at 30 wt%, 45 wt% and 55 wt% fibre content, with 95% confidence interval error bars.

- This significant influence after conditioning is consistent with predictions based upon micromechanical modelling
- In order to fully understand the origins of these differences, characterisation of Interfacial Shear Strength and fibre orientation also required in future works

6. Conclusions

- SEM is required for accurate characterisation of FGF CSA; FGFs frequently show skewed cross-sections
- Sized FGFs have improved tensile properties over CGFs; failure behaviour of FGFs is different to CGFs
- Use of FGFs leads to increased residual fibre length at same wt% of fibre when compared to CGFs
- Improved DaM composite tensile properties with FGFs only noted at high fibre weight fractions
- Significant improvement in boiling water conditioned composite tensile properties with FGFs

7. Acknowledgements

The authors of this paper would like to thank Nippon Electric Glass for providing both the glass fibres and composites used in this study, and for their contribution to funding the research conducted. The authors would also like to thank the International Strategic Partnership Fund of the University of Strathclyde for additional funding of the project.