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Strain rate dependency of compressive response of hybrid composites

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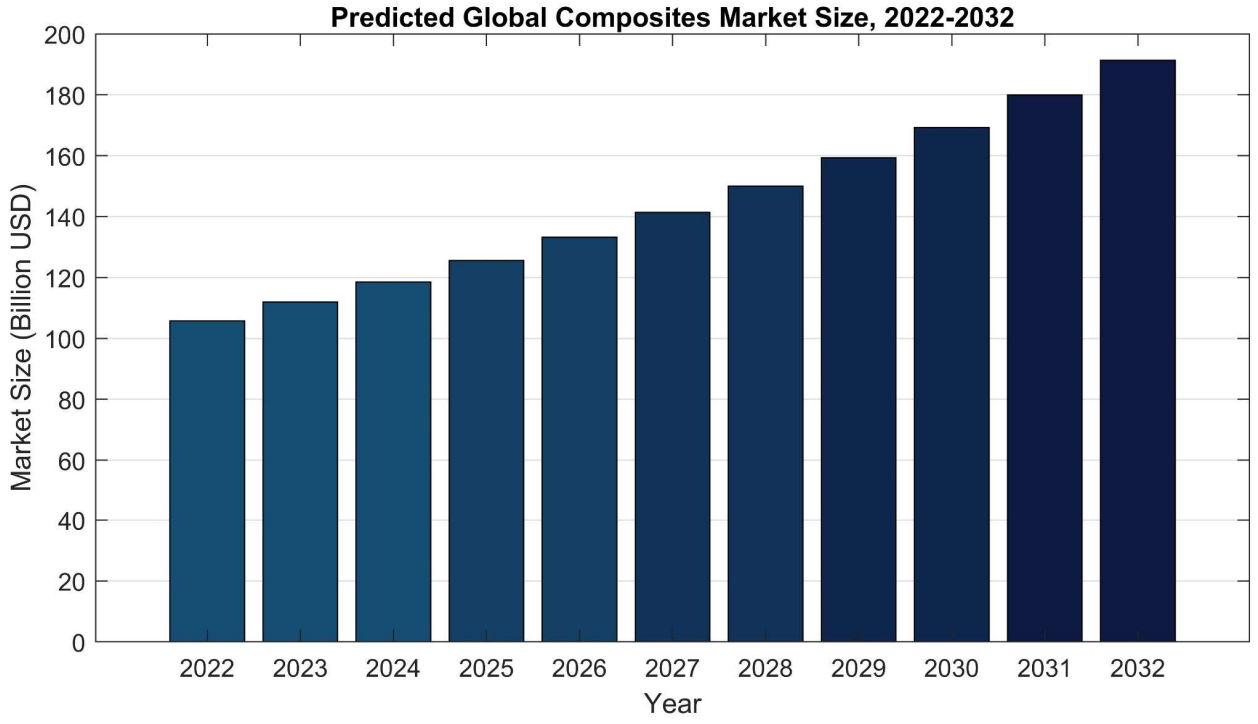
Background

The composite industry expected to grow by 80% in the next 10 years.

Sustainability is a key focus for industry.

Thermoplastics offer a recyclable solution.



[1]

Background

[2]

Lightweight composite structures are desired to reduce vehicle weight in the automotive industry.

Example of this include battery covers and body panels.

Continuous fibre composites offer high specific mechanical performance but are to expensive for large scale automotive.

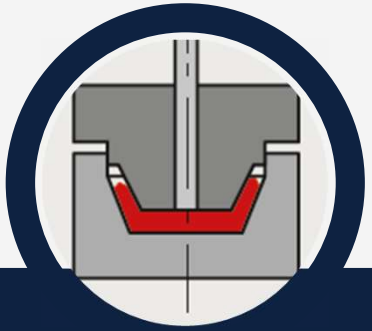
Discontinuous fibre composites offer a lower cost solution but have poor mechanical properties.

Hybridisation is a method of improving properties.

Research Objectives

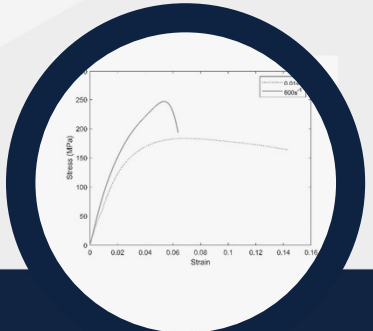
Manufacture of Hybrid Composite

Manufacture hybrid composite using a 2-step process



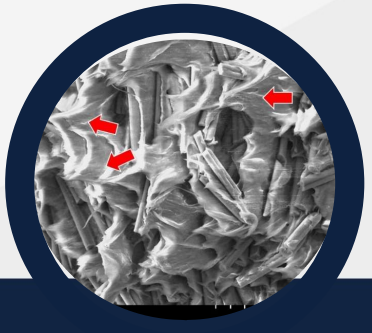
Manufacture of Short Fibre Composite

Manufacture short fibre composite through compression moulding



Observe Strain Rate Dependence

Look at mechanical properties under quasi-static and high strain rate



Observe Temperature Dependence

Characterise material at 2 strain rates with multiple temperatures

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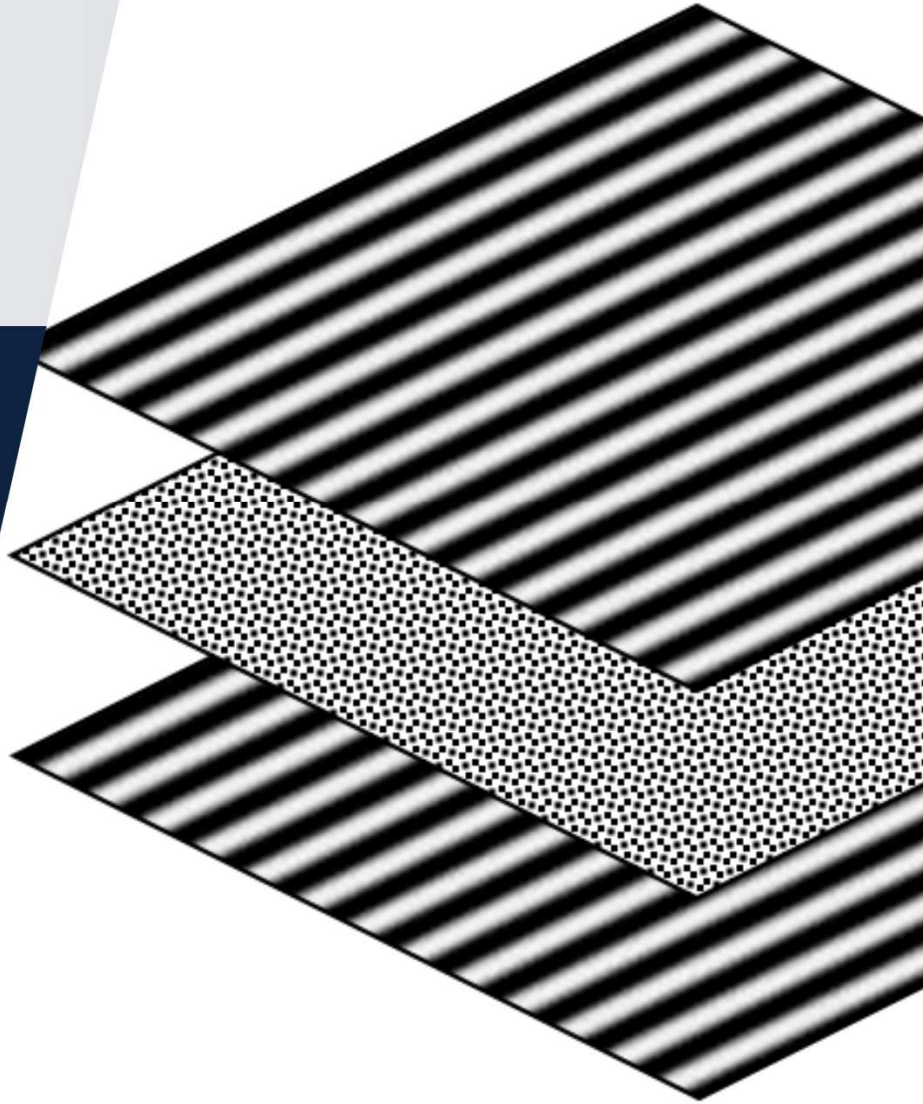


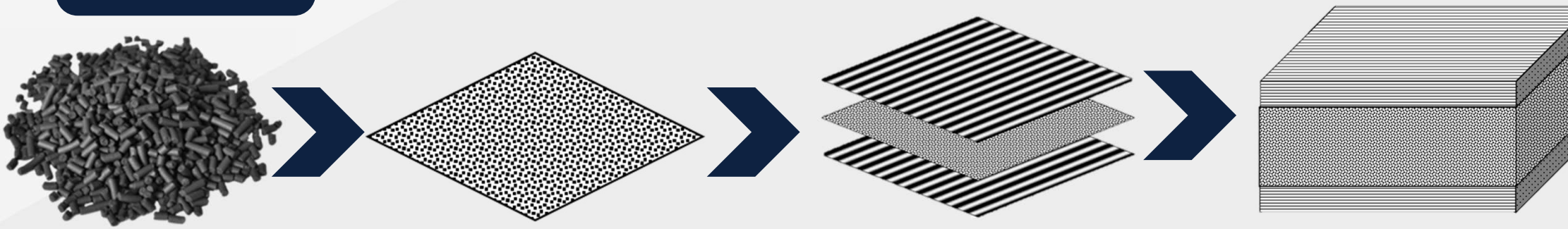
MANUFACTURE OF HYBRID COMPOSITE

Short fibre material

Short fibre PEEK/CF (0.15mm fibres, 25%Vf)

Hybrid material 2-Step Process

Short fibre PEEK/CF + UD PEEK/CF (60%Vf)

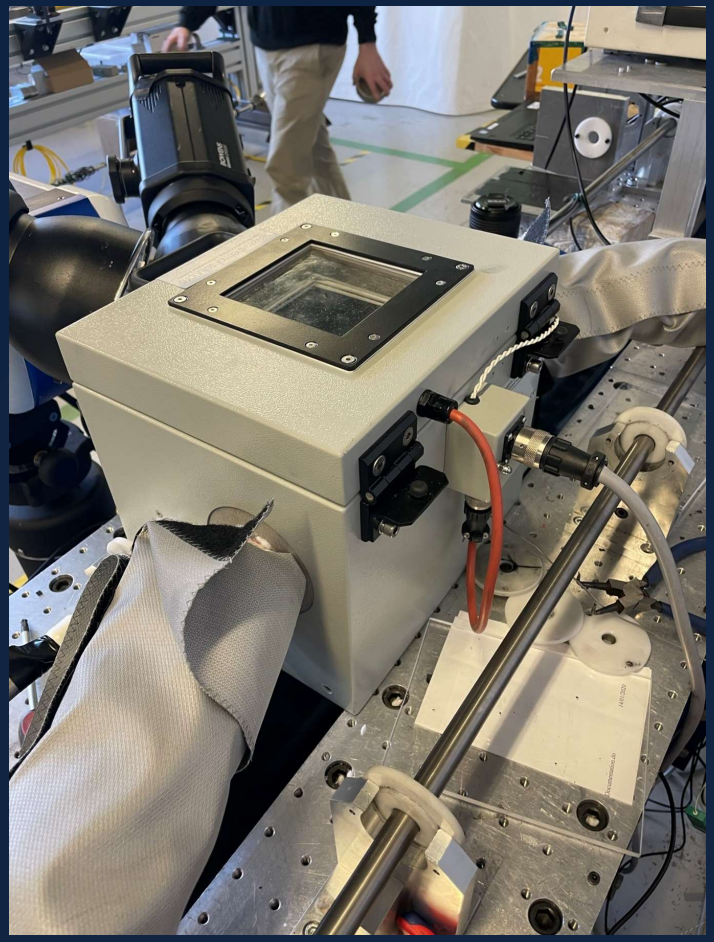


Testing Methods

High strain rate testing carried out using a Long Split Hopkinson Pressure Bar and Long Tensile Split Hopkinson Bar

Video was capture using a Kirana 05M high-speed camera at 300,000-500,000fps to allow DIC

Environmental clamber with oven and liquid nitrogen used to vary temperature from -50 to +85°C

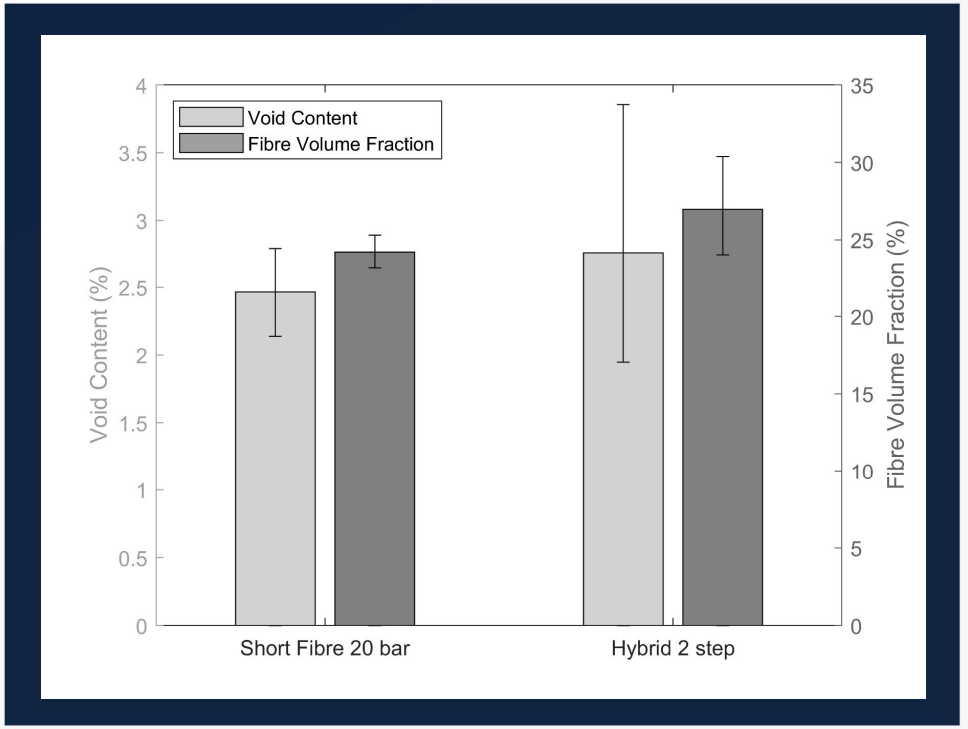


Manufacturing Quality

Quality analysed through density measurement and acid digestion

Void content between 2 and 4% for both materials

Fibre content higher in the hybrid material due to the UD layers

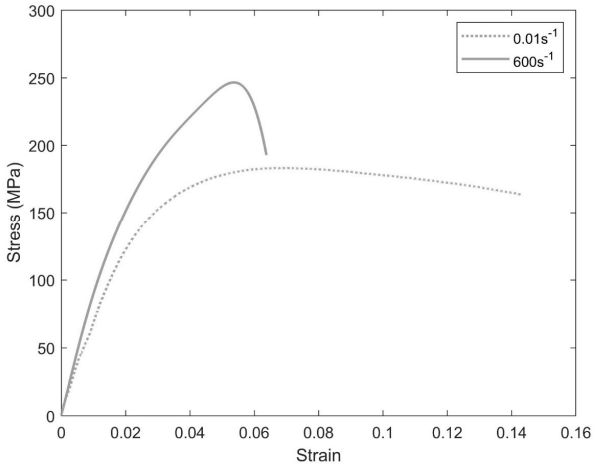


Compressive Strain Rate Dependence

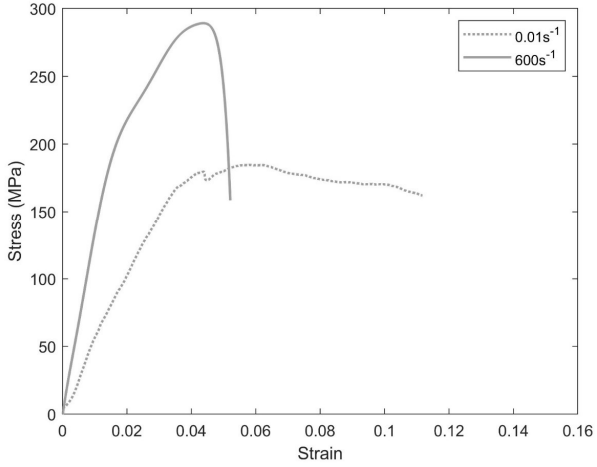
Large strain rate dependence observed in both materials

Increase in both strength and stiffness observed

Focus take into compressive strength



Short fibre composite

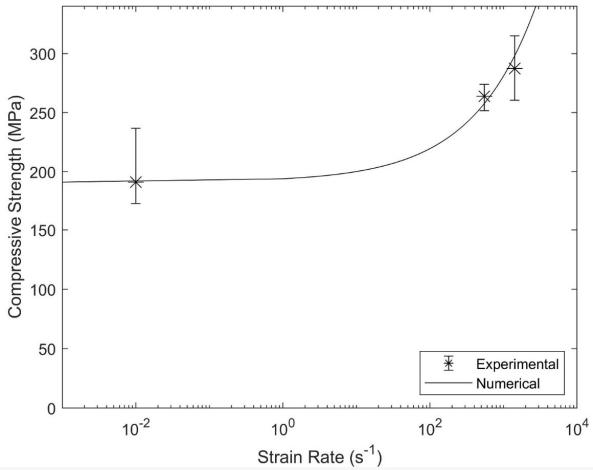


Hybrid composite

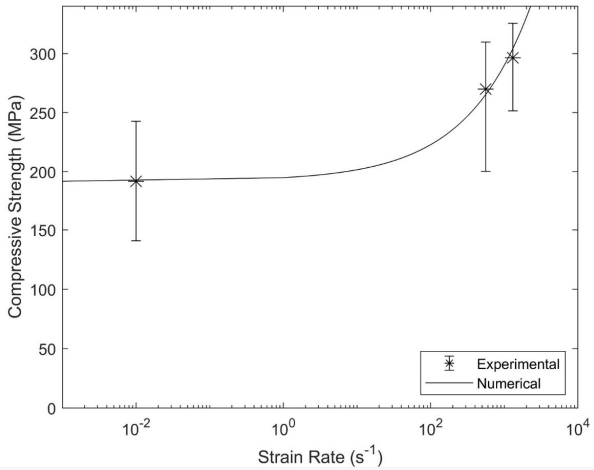
Compressive Strain Rate Dependence

High strain rate dependence observed for both material

Hybrid material showed a higher rate dependence due to the UD layers constraining the short fibre core



Short fibre composite



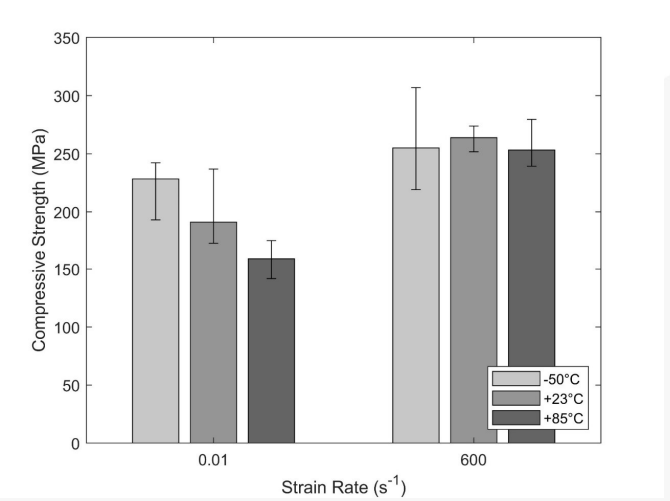
Hybrid composite

Compressive Temperature Dependence

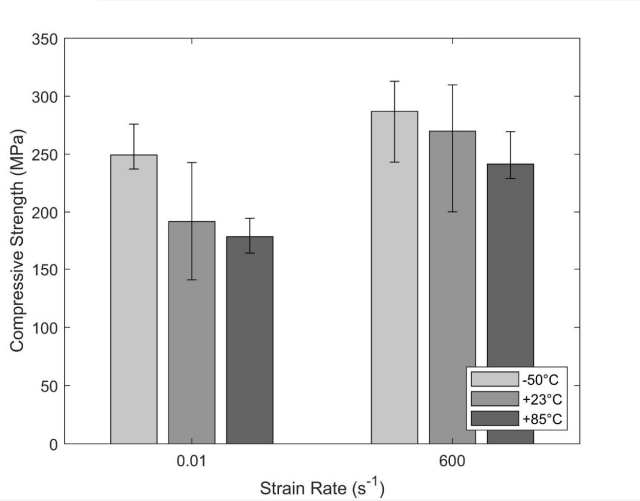
Under quasi-static conditions both materials had reduced strength with increased temperature due to the softening of the PEEK matrix

At higher strain rates the short fibre showed minimal rate dependence due to fast fracture not allowing time for matrix plasticity

The hybrid material shows the same temperature dependence at both rates as the UD layers slow the fracture allowing plastic deformation to occur

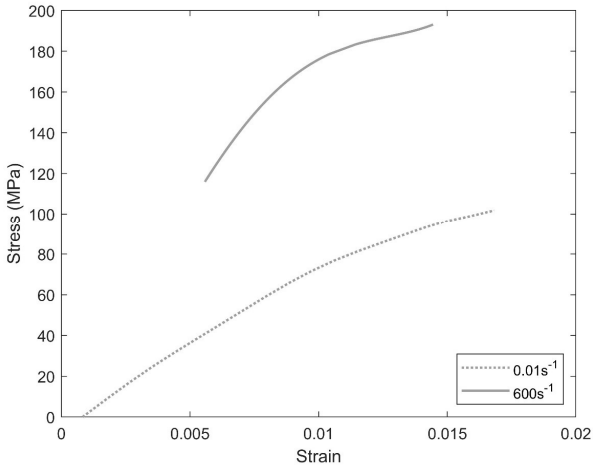


Short fibre composite

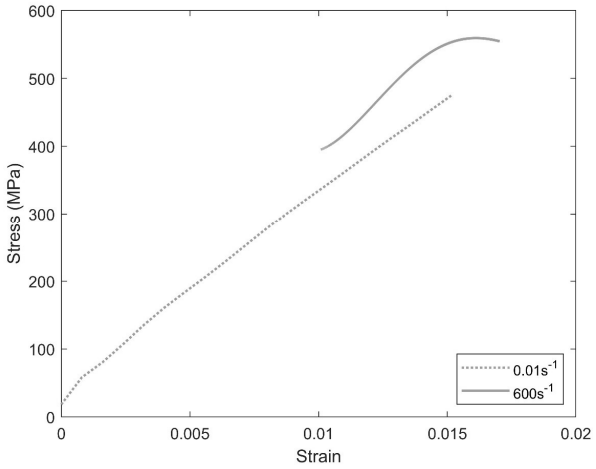


Hybrid composite

Tensile Strain Rate Dependence



Short fibre composite

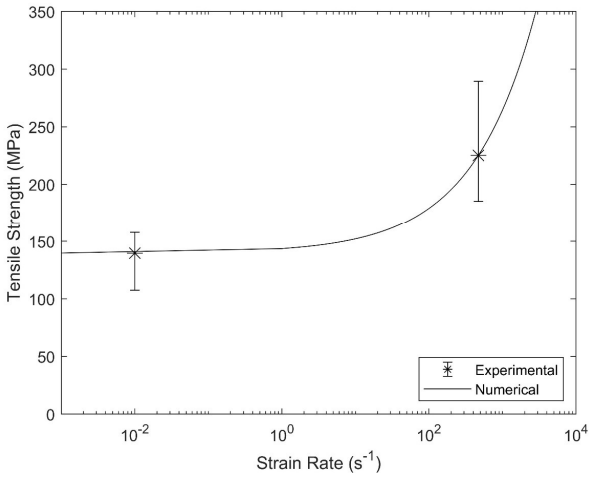


Hybrid composite

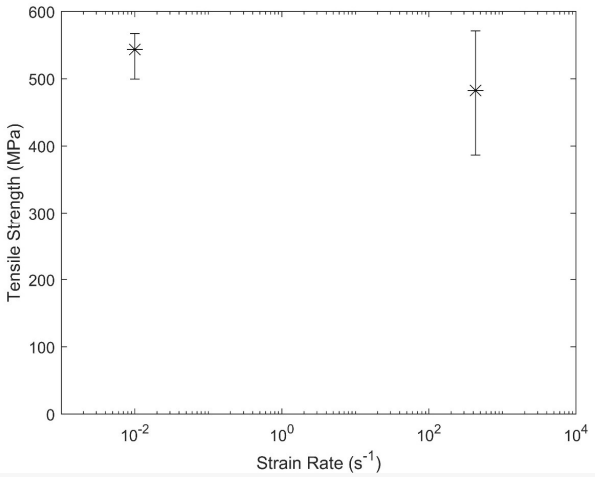
Similar to compression the tensile behaviour showed significant rate dependence

Due to large sample dynamic equilibrium was achieved later so full stress-strain curves could not be obtains

Tensile Strain Rate Dependence



Short fibre composite

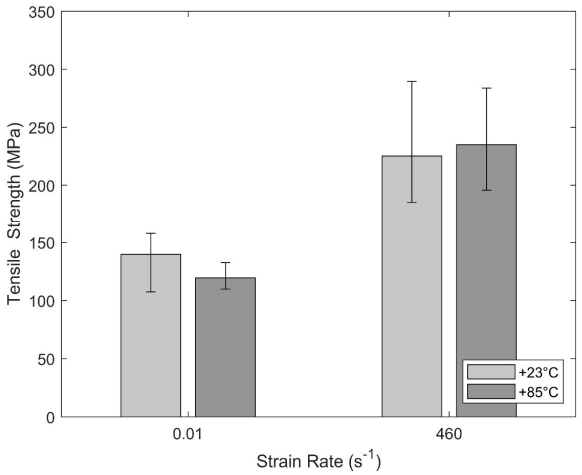


Hybrid composite

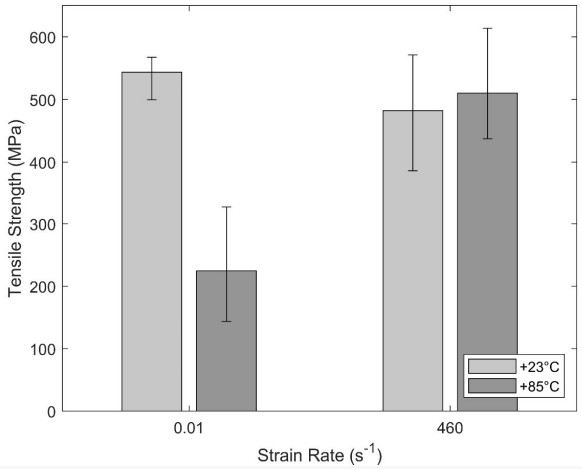
The short fibre material showed the largest strain rate dependence in tension

The hybrid material, however, showed no strain rate dependence due to properties being UD dominated

Tensile Temperature Dependence



Short fibre composite



Hybrid composite

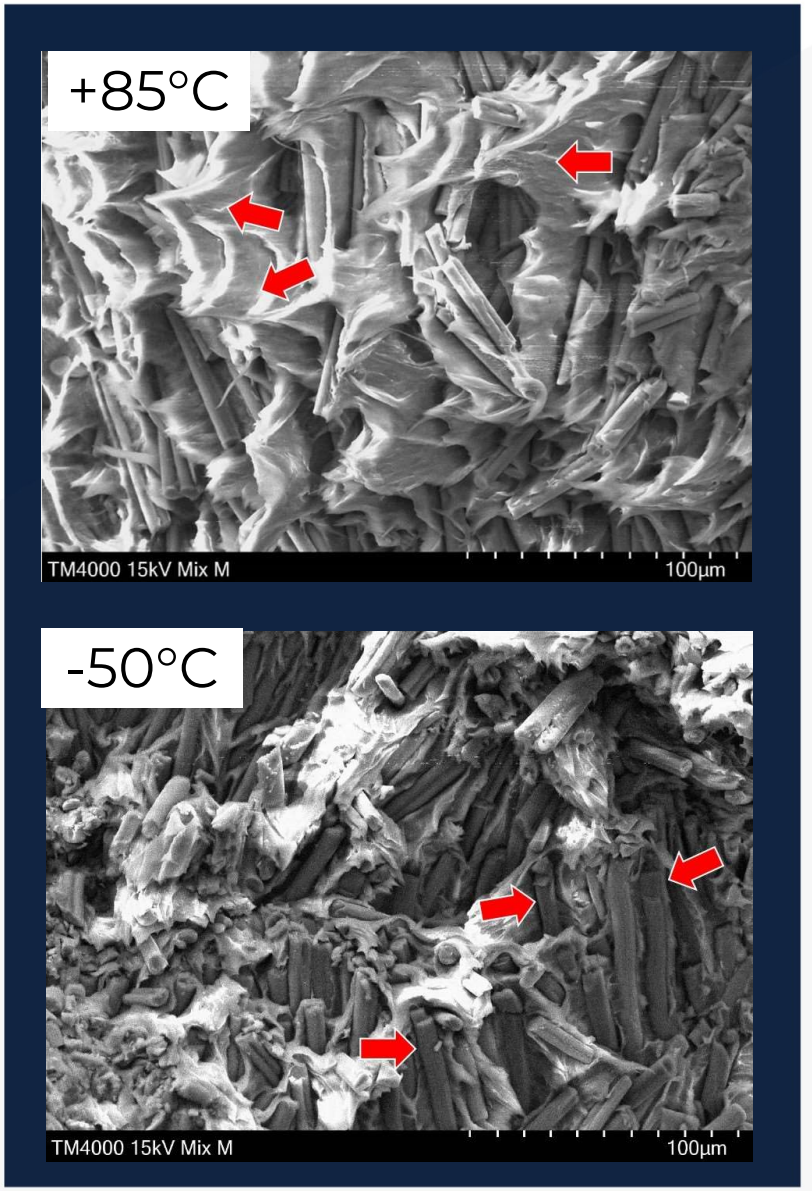
The temperature dependence of the short fibre material was the same as in compression

The hybrid material showed no temperature dependence at high rate but under quasi-static condition a large drop was observed with increase temperature due to plasticity between the UD and short fibre layers

Discussion

In compression fractographies showed:

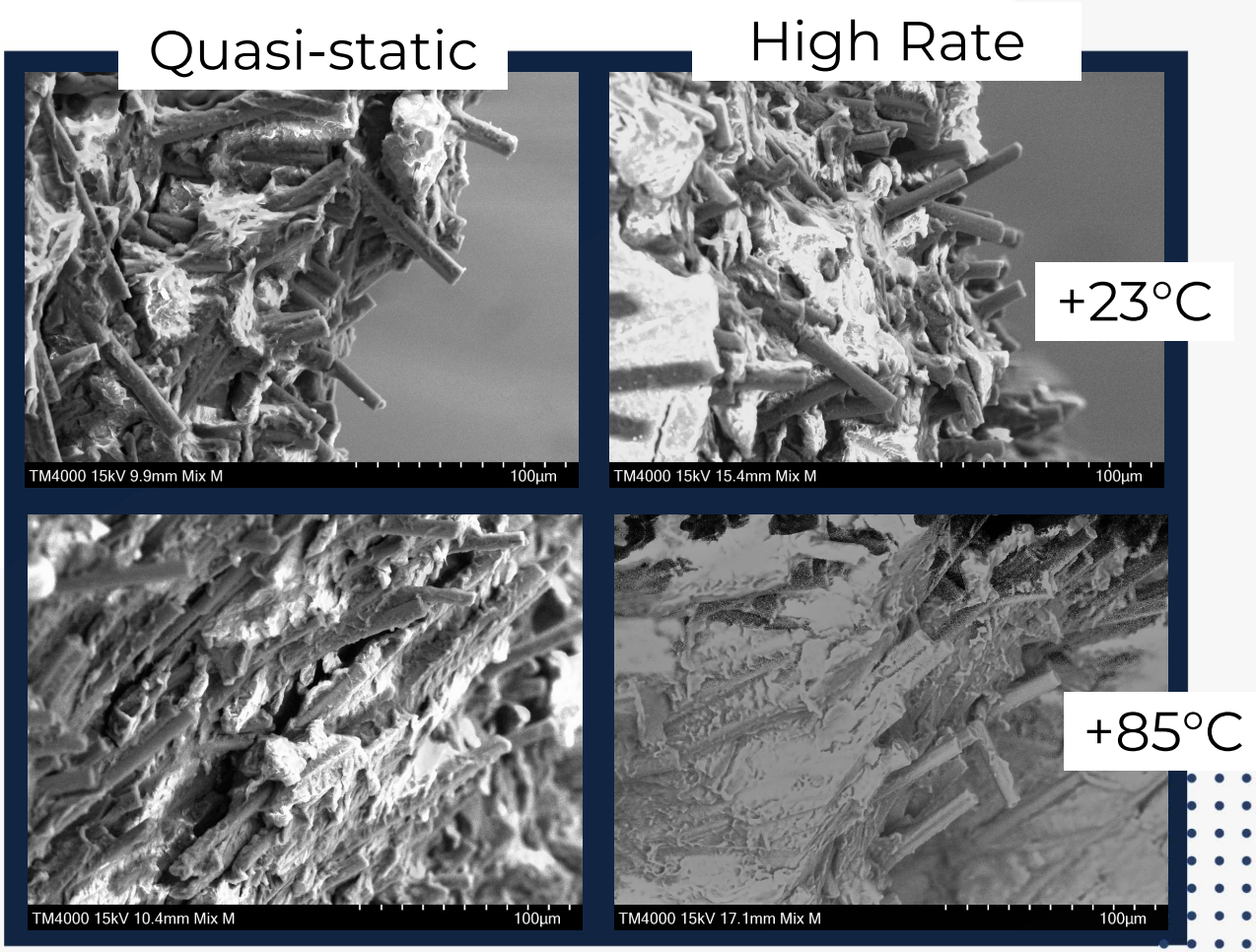
- Brittle failure of the fibre matrix interface at -50°C
- Increased plastic deformation of the matrix at +85°C

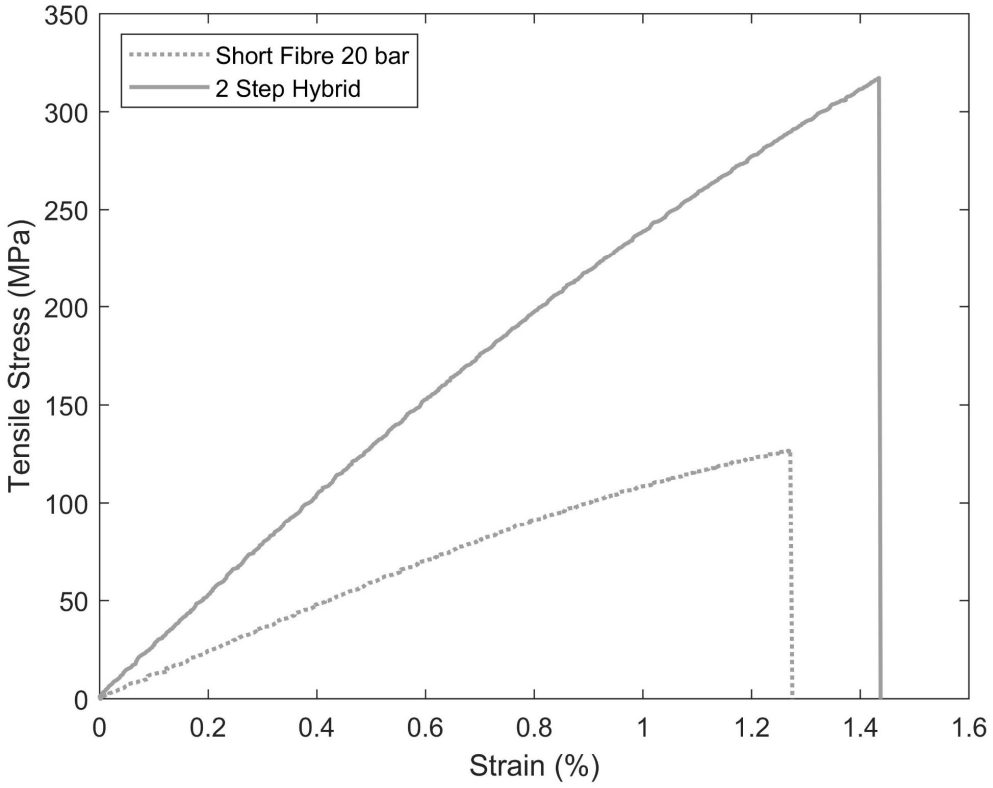


Discussion

In tension fractographies showed:

- Main failure mechanism of fibre pull-out
- Brittle failure at high strain rates
- Increase plasticity at higher temperatures





CONCLUSIONS

- Short fibre and hybrid material manufactured through compression moulding process
- Compressive strength for both materials showed high strain rate dependence
- Hybrid material showed greater strain rate dependence in compression
- In tension only short fibre material showed strain rat dependence
- SEM showed increased matrix plasticity under increased temperature

ACKNOWLEDGEMENTS

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REFERENCES

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[2] https://www.automotivemanufacturingsolutions.com/ev-battery-production/thinking-outside-the-box-lightweight-battery-enclosures/42124.article

THANK YOU

CONTACT DETAILS


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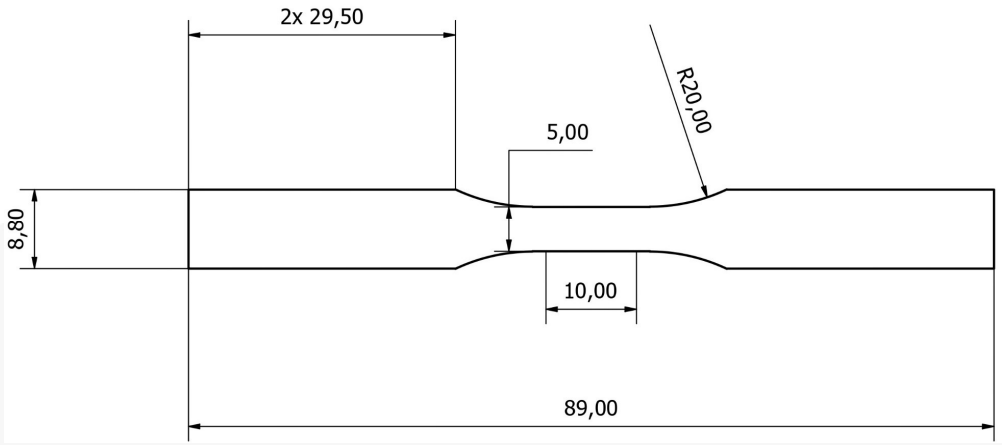
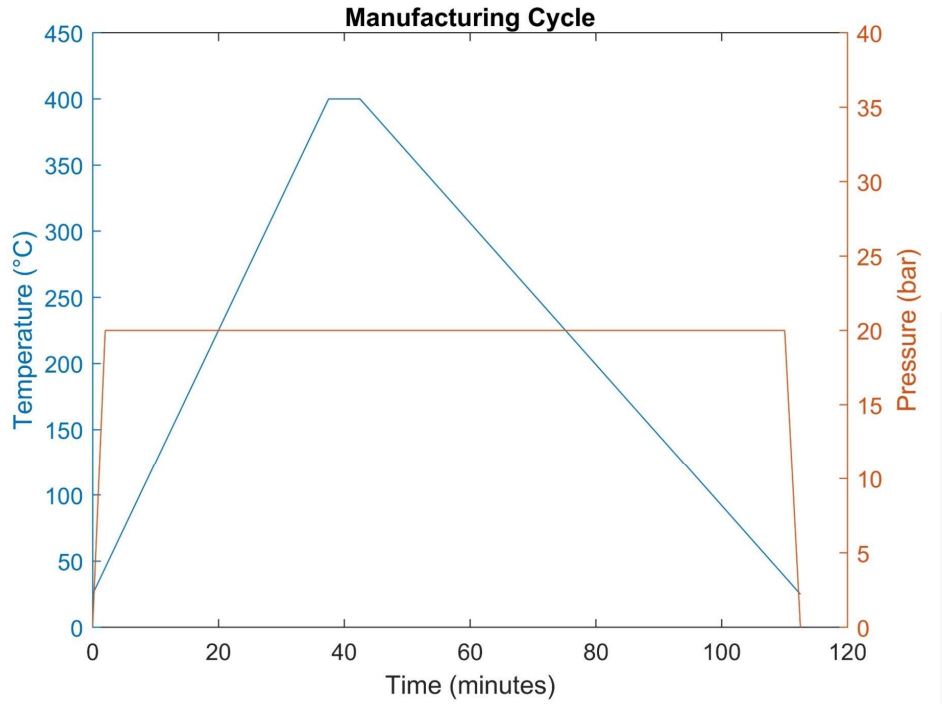
Sample Size and Clamping

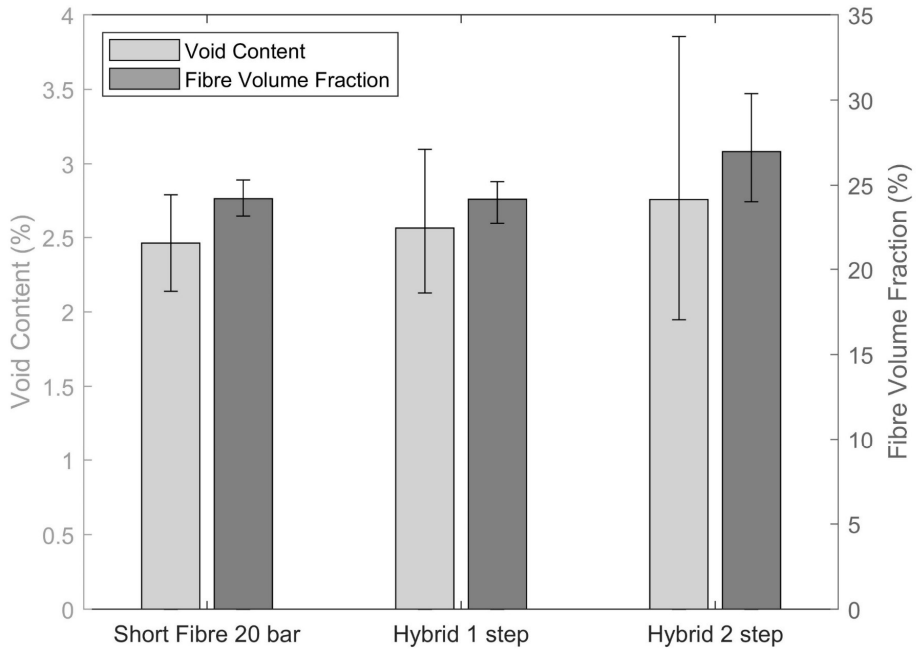
Compressive Sample



Tensile Sample

Hybrid Manufacturing Compared





Hybrid Manufacturing Compared