University of BRISTOL

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In situ strain sensing during the manufacture of fibre reinforced composites using optical fibres

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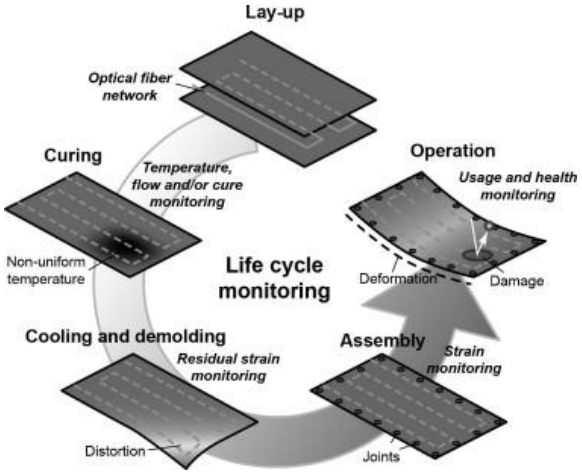
northwest composites centre

UKRI Engineering and Physical Sciences Research Council

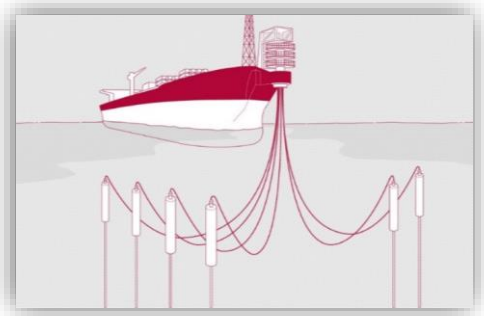
Presentation outline

- Structural health monitoring of composites
- Defect introduction during composite manufacture
- Global-local strain measurement concept
- Experimental case studies:
    1) Braiding process monitoring
    2) Resin infusion monitoring
    3) Curing process monitoring
- Concluding remarks

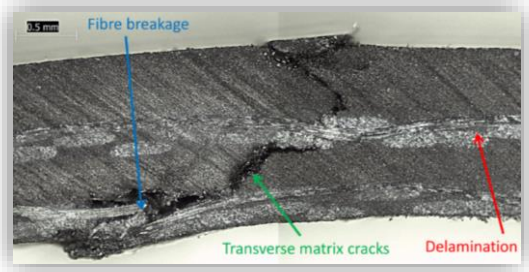


[Minakuchi et al., Compos. Part A, 42 (2011) 669-676]

The need for structural health monitoring



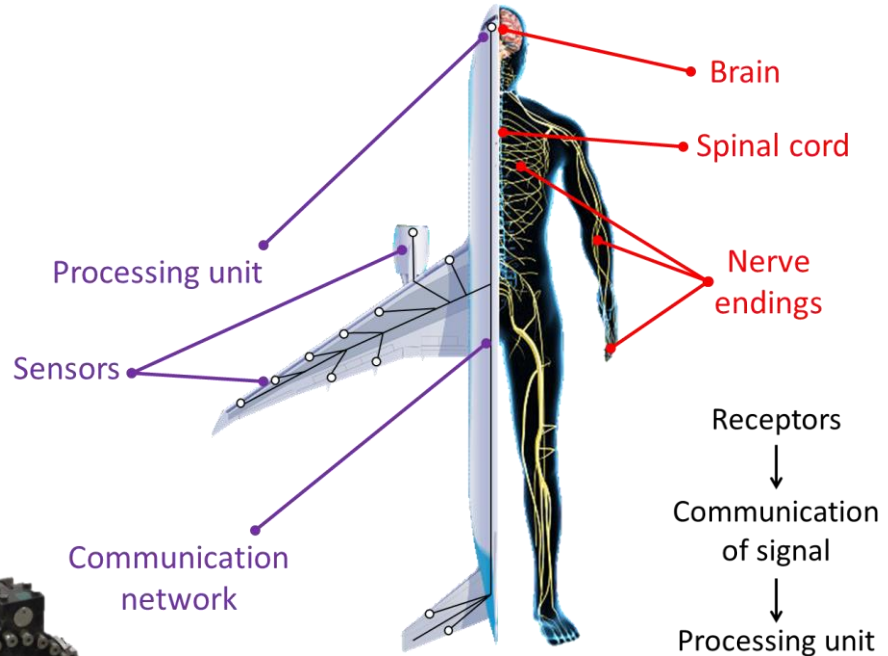
Magma's single leg offset riser (SLOF) [1]



Damage mechanisms in composite materials [3]

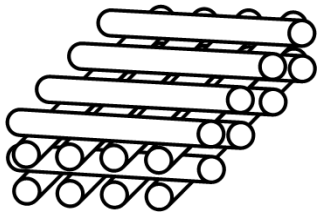
Magma m-pipe [2]

Heidrun High Pressure Drilling Riser [4]



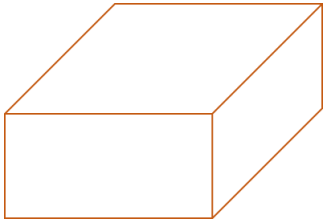
[1] https://www.magmaglobal.com/risers/magma-riser/
[2] https://www.victrex.com/en/news/2017/01/magma-victrex-partnership
[3] Chandarana et al., Appl. Comp. Mats. (2016)
[4] http://pangaeadrillingtech.com/composite-drilling-risers

Defect introduction during manufacture



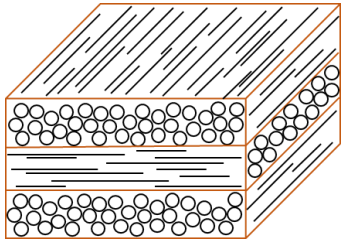
Fibres

\+

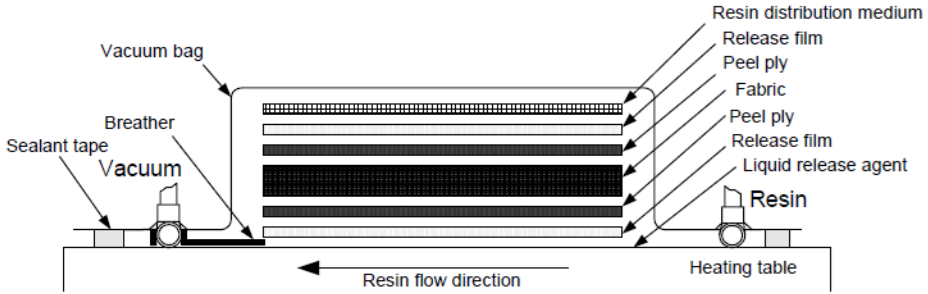


Polymer

=



Composite



Vacuum resin infusion process

[Goren & Atas, Arch. Mater. Sci. Eng. 34 (2008) 117–120]

Possible defects:

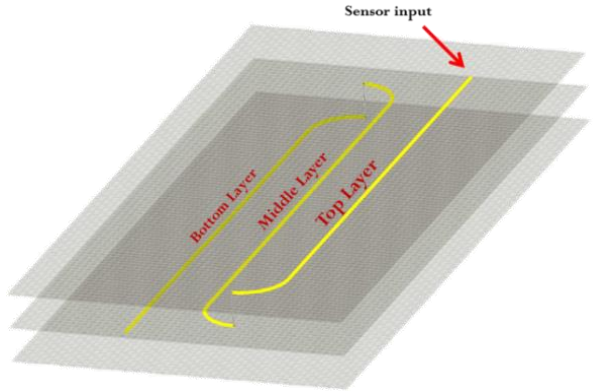
- Voids
- Dry regions
- Resin rich areas
- Fibre misalignment
- Moisture ingress

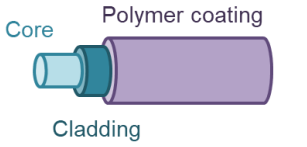
→ ~50% of failures caused by defects [1]

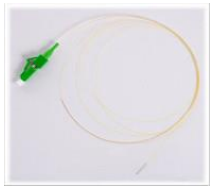
[1] H.P. Konka, PhD Thesis (2011)

Global-local strain measurement concept

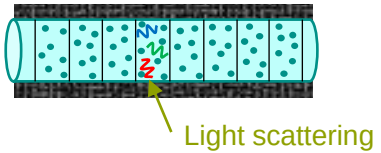
- Discrete measurement points along the full length of the fibre
- Optical frequency domain reflectometry (OFDR)
- OF has a unique Rayleigh scattering profile
- Distributed strain/temperature measurement
- Resolution of 1 με or 0.1°C

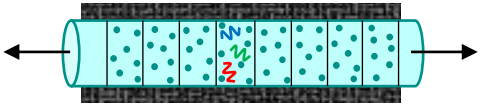


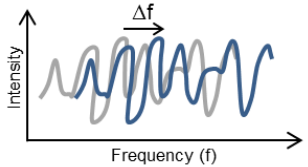




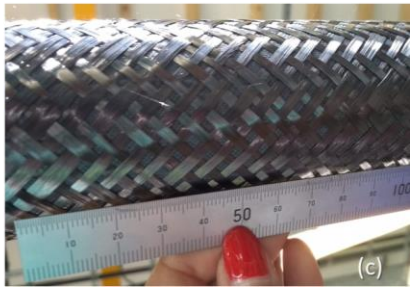
155 µm diameter, Polyimide coated optical fibre



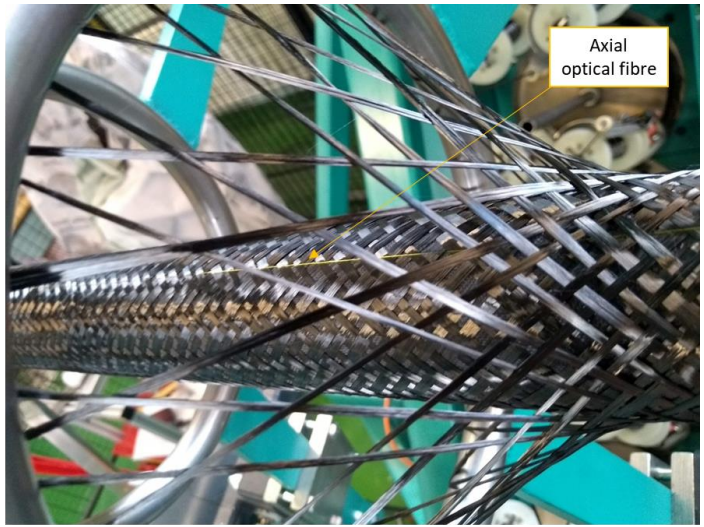




Case study 1: Braiding process monitoring



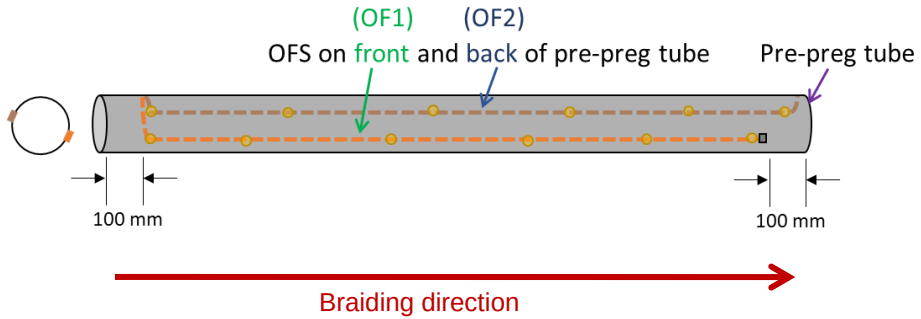
(a)

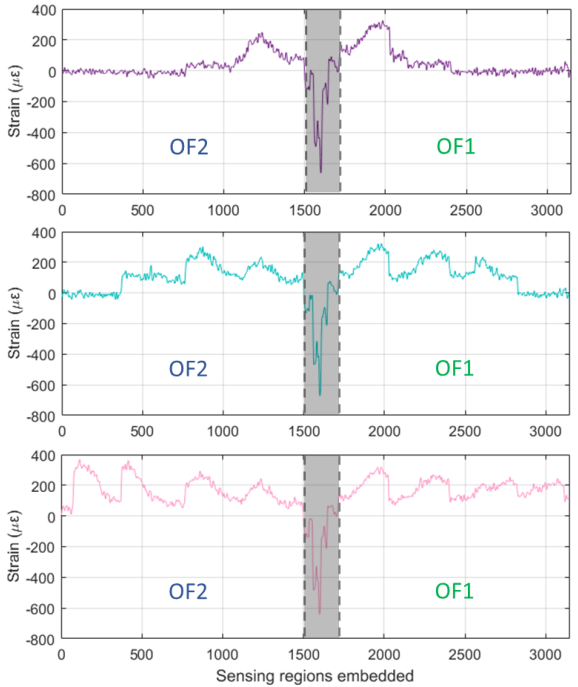


(b)

Preforming → Resin infusion → Curing → In-service

Case study 1: Braiding process monitoring

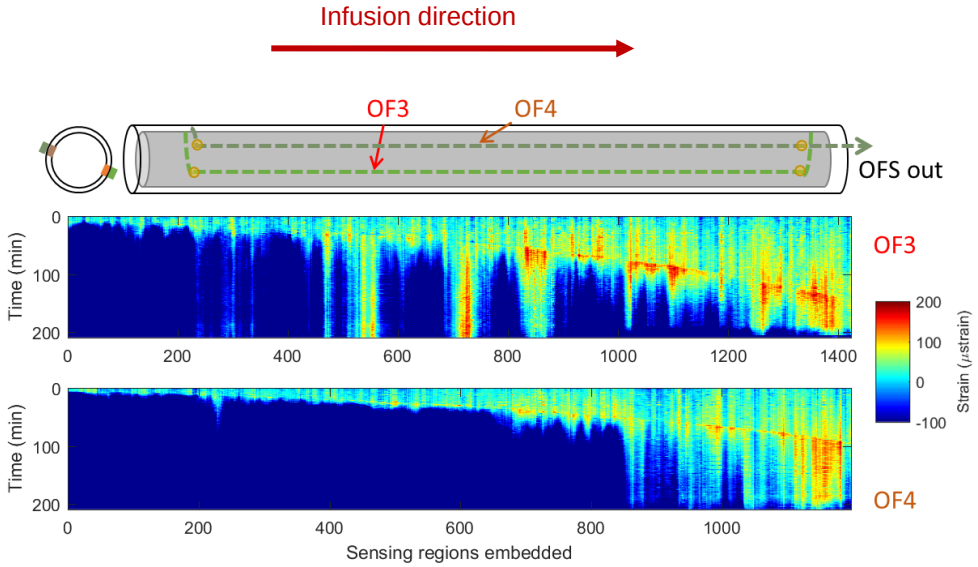


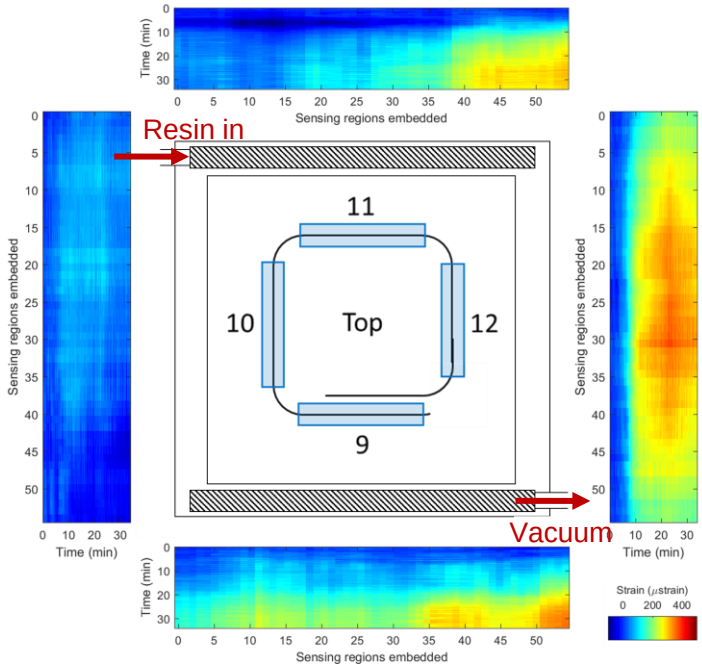


- Development of strain during application of first braid layer
- Peak strains observed in locations where adhesive was applied

Preforming → Resin infusion → Curing → In-service

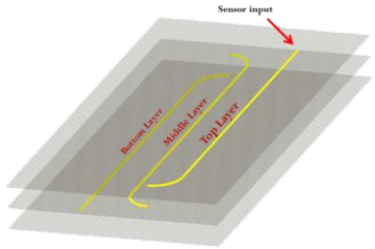
Case study 2: Resin infusion monitoring

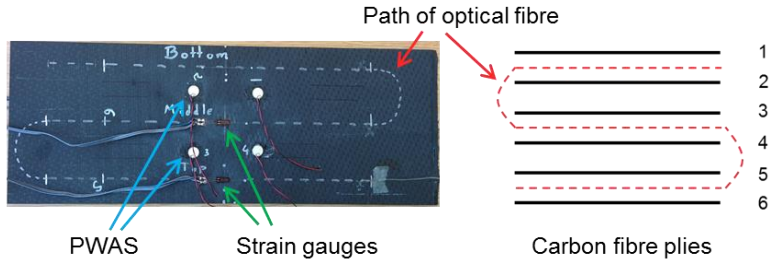


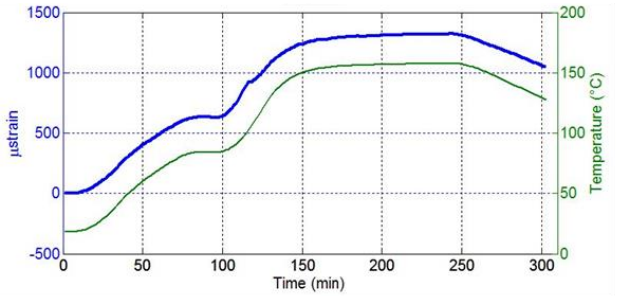


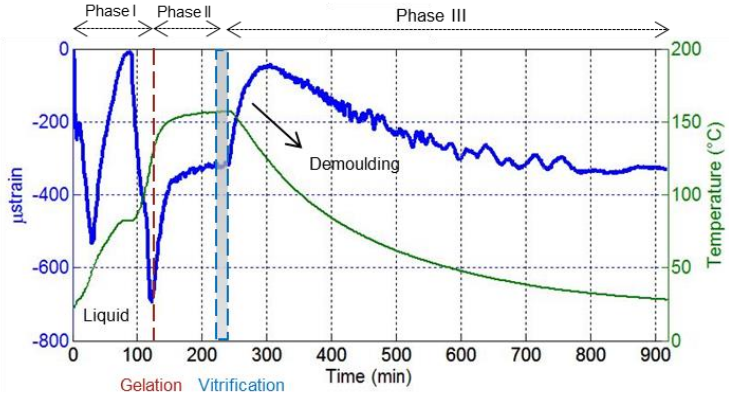
Preforming | **Resin infusion** | Curing | In-service

Case study 3: Curing process monitoring









Preforming | Resin infusion | **Curing** | In-service

Conclusions and next steps

- Advantageous during preforming versus currently available visual methods
- Strain gradients caused by infusion detected by embedded sensing
- Resin viscosity information can be extracted from strain developed during curing

Additional capabilities:

- Global-local strain monitoring of in-service components
- Combine with machine learning techniques such as ANN

Acknowledgements

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Thank you for your attention ☺

Any questions?

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