Active thermal management via embedded vascular networks

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Fibre reinforced polymer (FRP) composites are limited in high temperature applications by the matrix glass transition temperature, $T_g$. Above this temperature, mechanical strength is degraded as the matrix softens. A novel solution is active thermal management, which aims to reduce local matrix temperature. This can be achieved by circulating liquid or gaseous fluid through a network of internal passages, or vasculae. Potential benefits include increased operating temperature limits, increased mechanical performance at high temperature, reduced thermal creep/stress relaxation, and reduced thermal fatigue/thermo-oxidative ageing.

Initial research focused on investigating the use of air as a coolant. The viability has been proven by IR thermography of samples in 80°C, 3 m/s airflow.

Surface temperature reductions of 5°C to 10°C were observed (Fig. 1).

These results were supported by a finite-difference numerical model in MATLAB, which is under continued development to improve its capability and efficiency.

Ongoing research aims to investigate the performance benefits possible with this technology.

4-point bend flexural testing from ambient to 110°C to study effects of vasculue spacing and coolant flow rate on flexural modulus.

Initial results suggest vasculue presence has negligible effect, with some indication of post-cool down improvement of up to 4% (Fig. 2).

Fig. 1: Comparison of experimental (left) and simulation (right) results for coolant flows of 0.0 l/min (top) and 10.0 l/min (bottom)

Fig. 2: Temperature-Flow-Modulus map for specimen with vasculue spacing = 20 mm