David Allenby – Uni ID: 10521802

BEng (Hons) Mechanical Engineering with Composites

An Investigation Into Heat Transfer In Composite Heated Tooling

Context

As the demand of composites increases the need to adopt environmentally friendly, time and money saving processes becomes more imperative. Conventional curing methods, such as autoclaves and ovens, require large amounts of capital investment, energy usage and have long cure cycles. Heated mould tools can easily cure at low temperatures, and with a comparatively small energy requirement, however are not used for medium and high temperature cures, reducing the number of industrial applications.

Aims

- Ascertain and evaluate the thermal losses involved in heated tooling for composite manufacture.
- Input of findings into computational simulations will allow theoretical prediction of the suitability of heated tooling for high temperature composite curing.
- Identifying effectiveness could provide a faster, environmentally sustainable, low-cost process of composite curing.

Objectives

- Take thermal readings of a heated mould tool during different temperature runs.
- Determine the average temperature differences for each temperature run.
- Where possible, results to be validated with multiple methods.
- Computationally analyse the mould tool to calculate the theoretical losses involved in higher temperature cures.

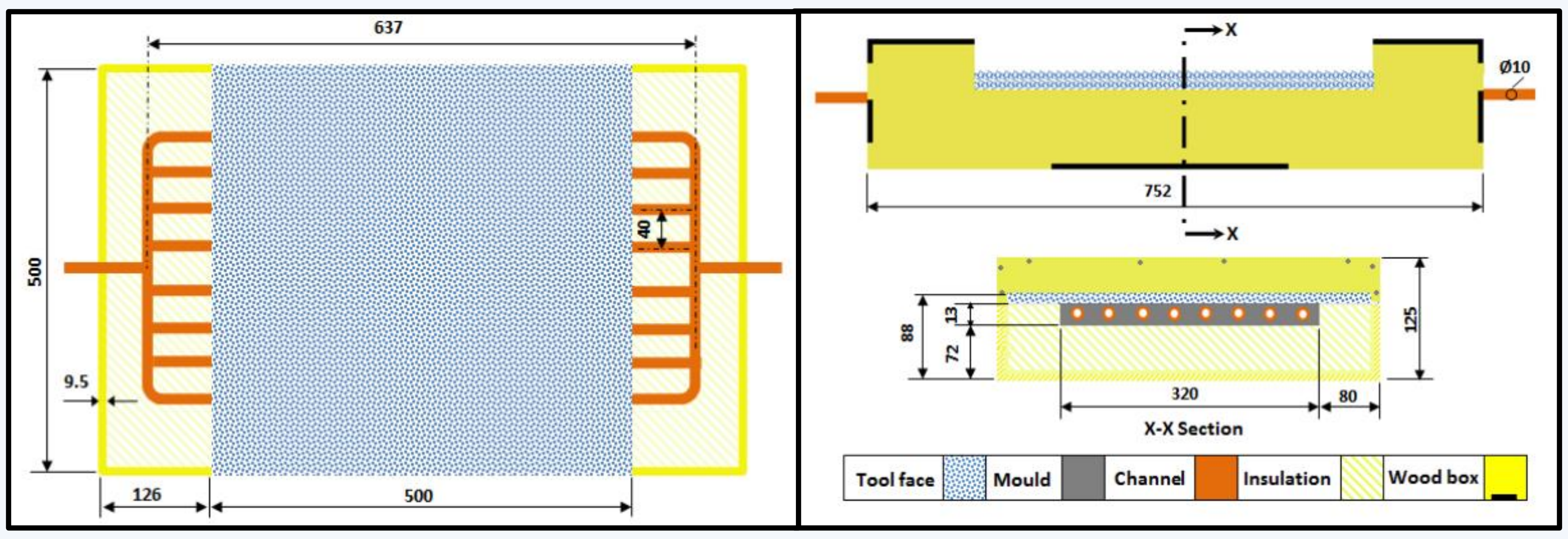

Figure 1. Mould tool schematic

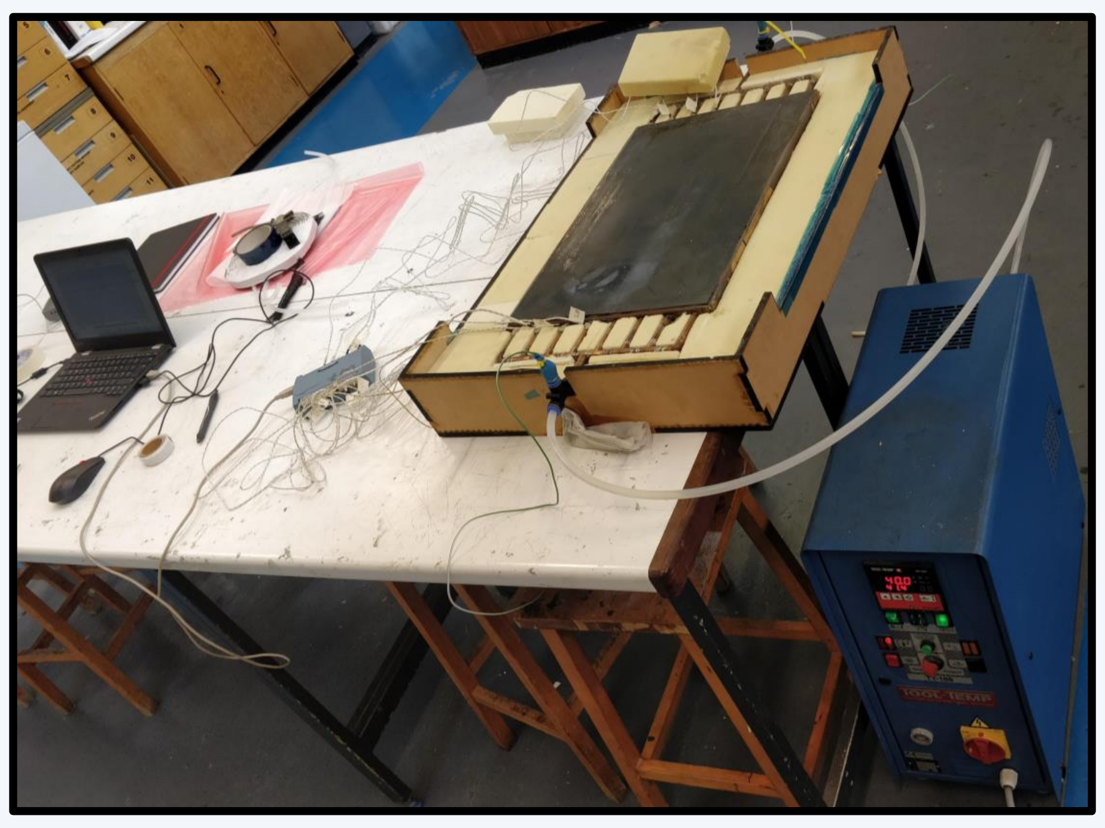

Figure 2. Experimental layout

Methods

Experimental testing

Testing was carried out on the heated mould tool, by using hot water. Thermocouples were attached to pipes at the inlet and outlet for one test and the curing block inlets and outlets for the other test measuring overall thermal loss and curing block thermal loss respectively. Data was captured every second for 5 minutes for test temperatures of 10°C intervals between and including 40°C and 90°C.

Computational simulations

Simulations were carried out on a model of the ideal mould tool. Thermal loads, similar to the experimental testing, were then applied to the model. The surface convection coefficient was changed so that the outcome of the simulations replicated the experimental data. Using this established value, higher temperature simulations were carried out to understand the increasing thermal losses.

Results

Thermal loss in fluid across entire apparatus at 90°C	0.299°C
Average curing block thermal loss at 90°C	3.01°C
Simulated thermal loss across entire apparatus at 90°C	1.1°C
Simulated thermal loss across entire apparatus at 120°C	1.5°C
Simulated thermal loss across entire apparatus at 180°C	2.4°C

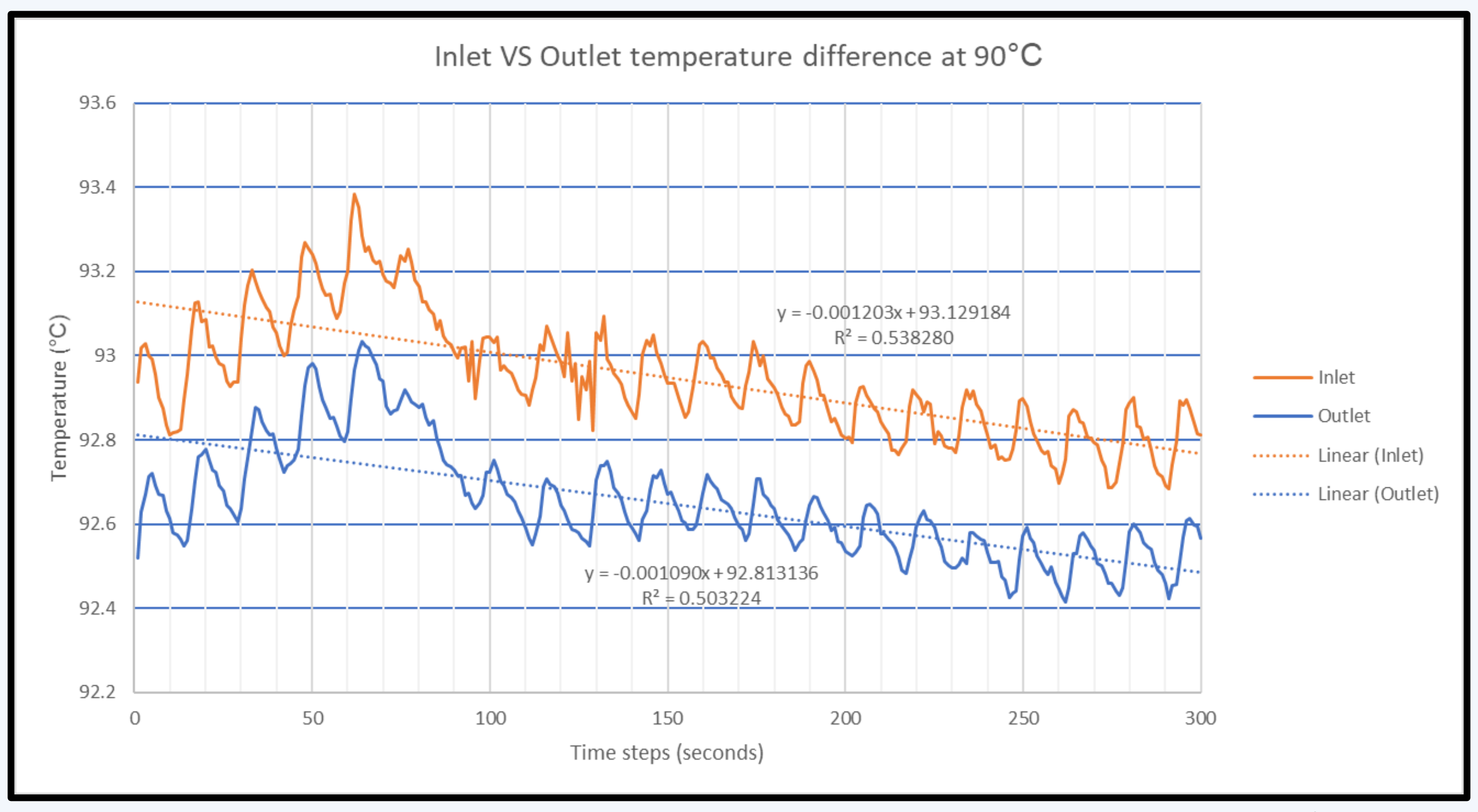

Figure 3. Experimental result graph - Inlet VS Outlet temperatures at 90°C

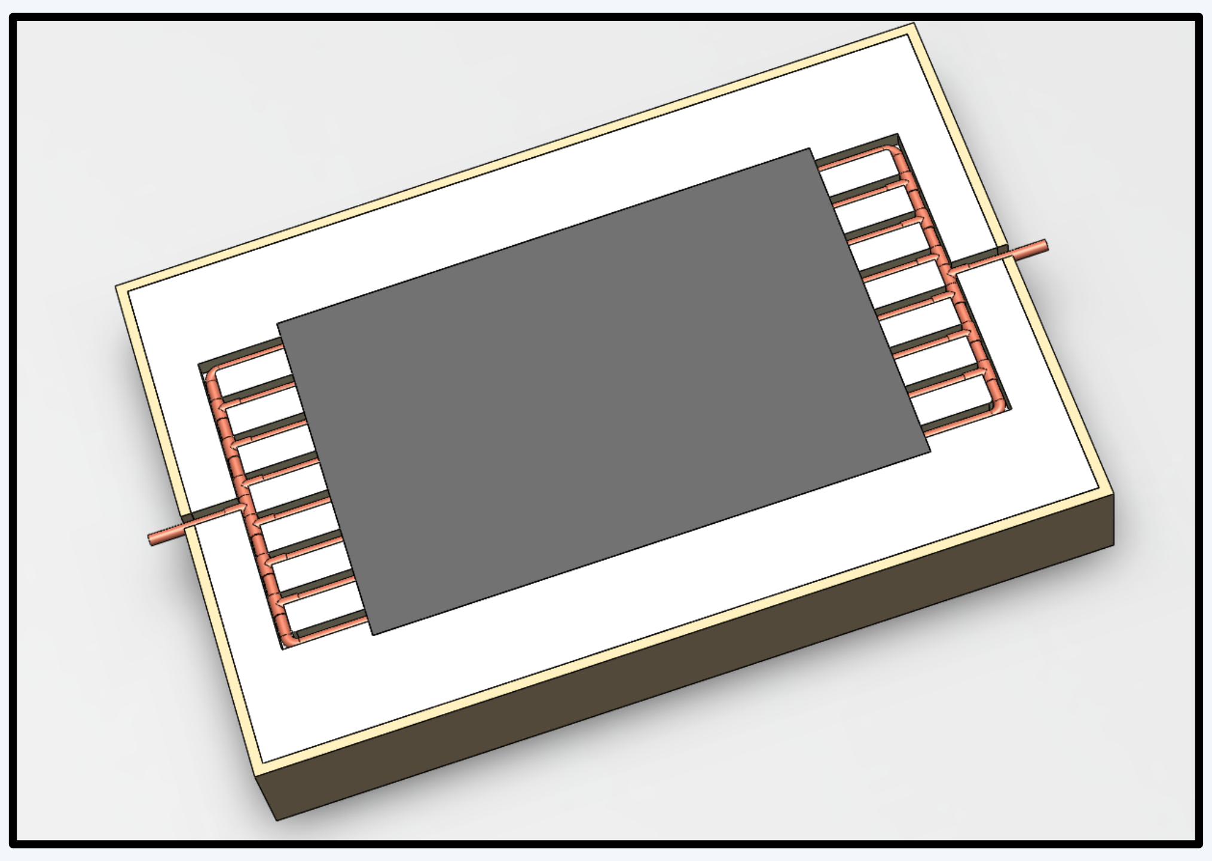

Figure 4a. Simulation model

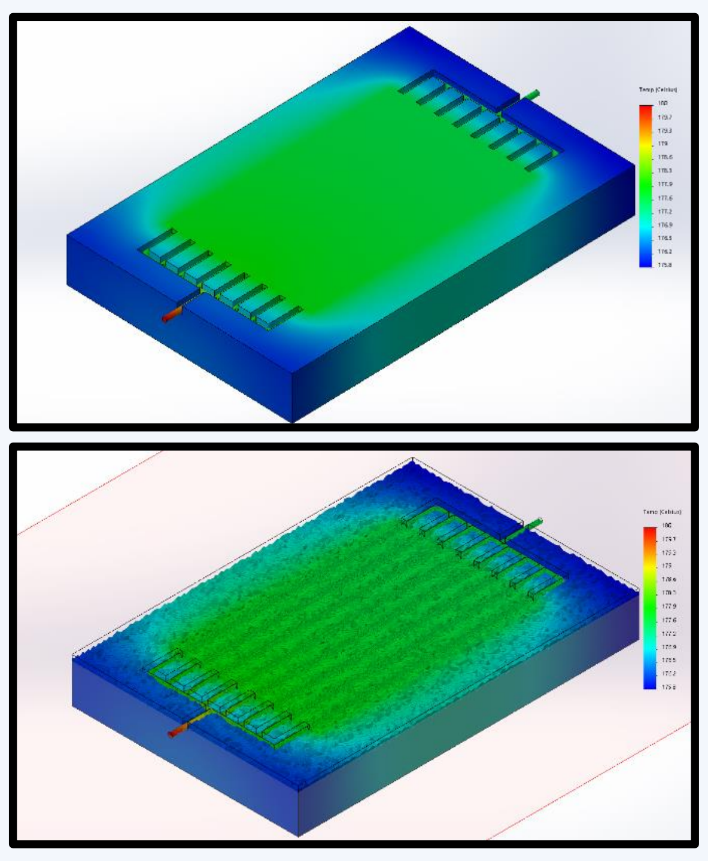

Figure 4b & 4c. Computational result – Thermal gradient at 180°C

Limitations of results:

- Thermocouples were not calibrated and connection with pipes varied.
- Limited experimental testing was collected.
- Simulations ran steady state studies.
- Simulations were limited by computational resources.
- Fluid flow is not considered in the simulations.
- The simulation model is based of the ideal model.

Conclusion

Experimental testing displays a clear correlation between thermal energy loss and input temperature. Simulations developed indicated a thermal loss of 1.25% at 120°C and 1.3% at 180°C.

Identifying this manufacturing tool as a contender to the increasing Out-Of-Autoclave sector through the reduction in energy used, space saved and reduced investment cost.

Recommendations for further work

- Capture more experimental data to validate results.
- Ensure calibration and correct positioning of thermocouples.
- Run more complex simulations with fluid flow.
- Investigate conventional methods of curing to compare energy efficiency.
- Rebuild the mould tool to allow for higher temperatures and pressure.
- Experimentally test with different flow mediums.