Efficiency and influence of heating device on wind turbine blades

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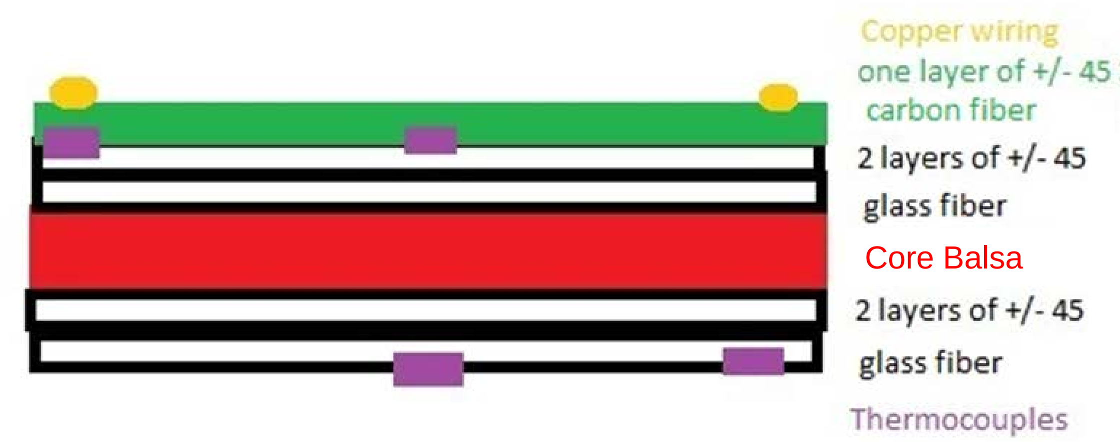
Agenda.

- Manufacturing of test panels with heating elements
- Heating signature of manufactured panels
- A degradation model based on the influence thermal fatigue of composite laminates with incorporated heating device.
- A thermal evaluation technique developed at Skellefteå Kraft by use of a mini helicopter equipped with thermal camera.

-A test method to study the de-icing process.

-A heat transfer modeled with FEM for de-icing developed by LTU.

Manufacturing of test panels, SICOMP (technique used today for wind power)



+ Test plates with improved design of heating by Bollebygd plast

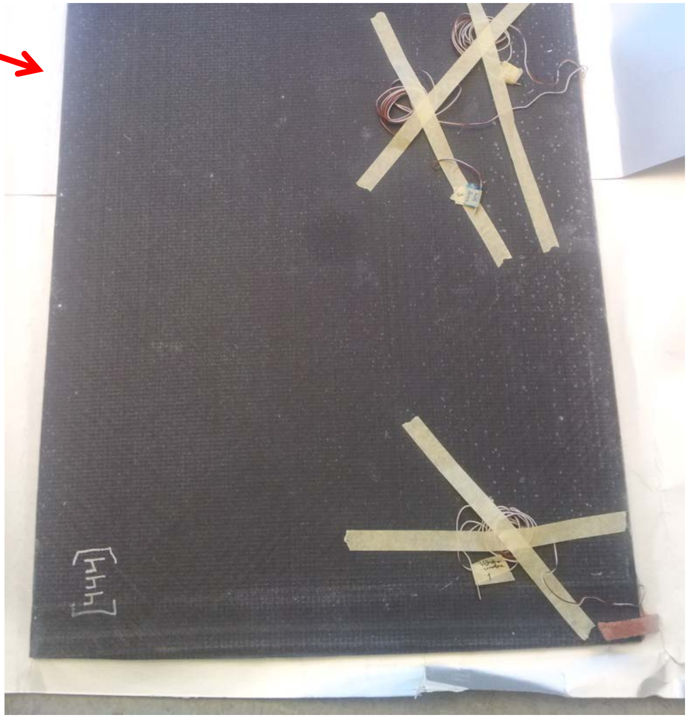
Heat signature room temperature

Sicomp+Bollebygd plast

Plate I

Problems:
- Hotspots
- Uneven temperature

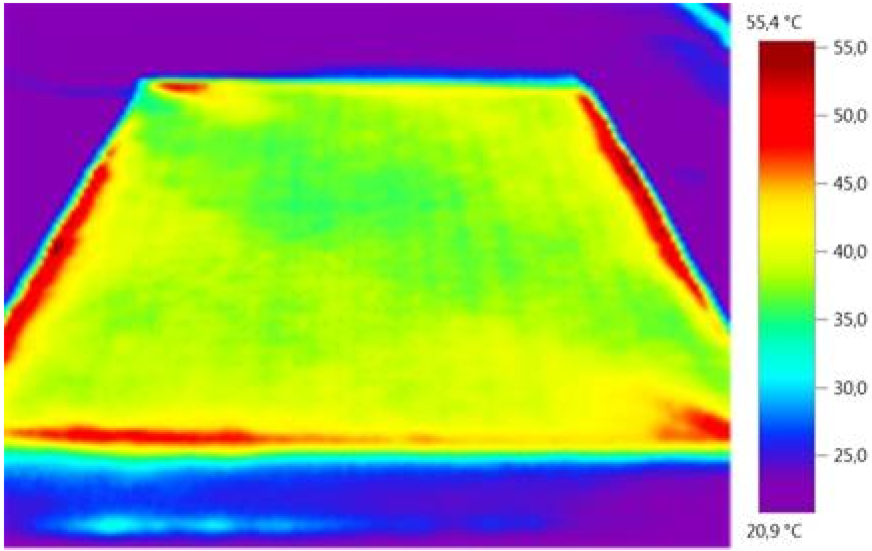
Plate II



Improvement:
- Good temperature profile
- Good electric connection

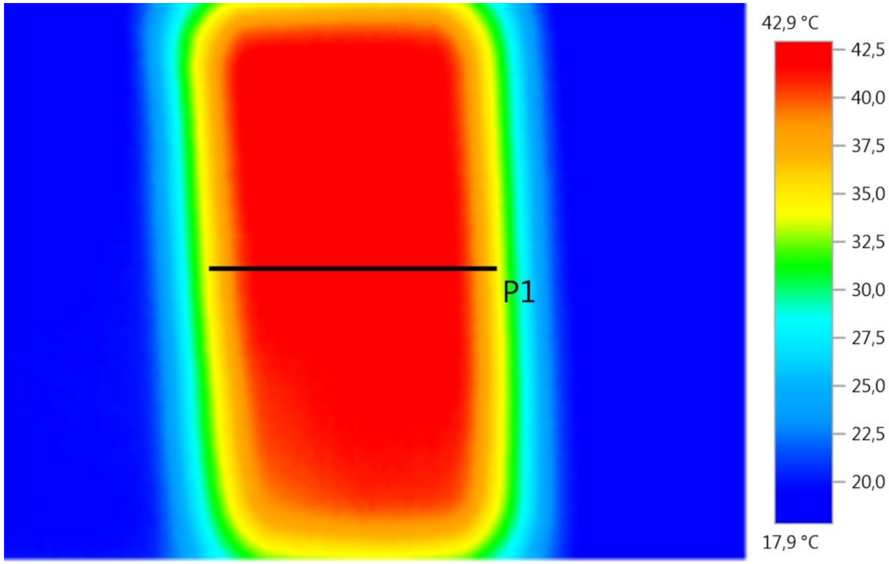
Heat signature room temperature

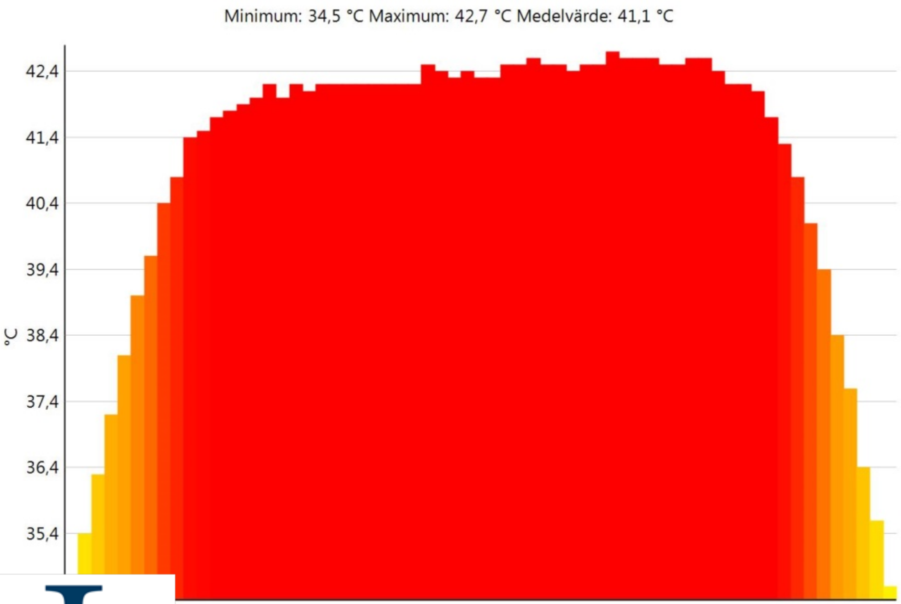
Plate I



Temperature: 37-55 deg

Heat signature room temperature Plate II

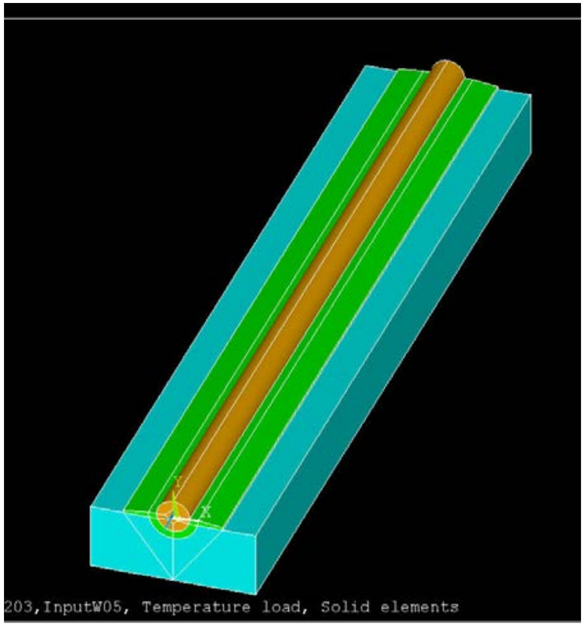




Degradation model; Possible problem areas

Example initially performed FEM analysis

- ✓ Stresses due to a not even temperature distribution
- ✓ Stresses due to ”hot-spots”
- ✓ Stresses in the connetion cupper plate (if it is used) to composite laminate
- ✓ Stresses in the connetion cupper wire to composite laminate
- ✓ Stresses in the transition zone between carbon fibre laminate (heated) and glass-fiber laminate



Figur 1 Example: Cupper wire in connection with composite laminate. Brown = cupper, Green = pure epoxy, Blue = composite

Effect of added and heated laminate

Realistic laminate construction

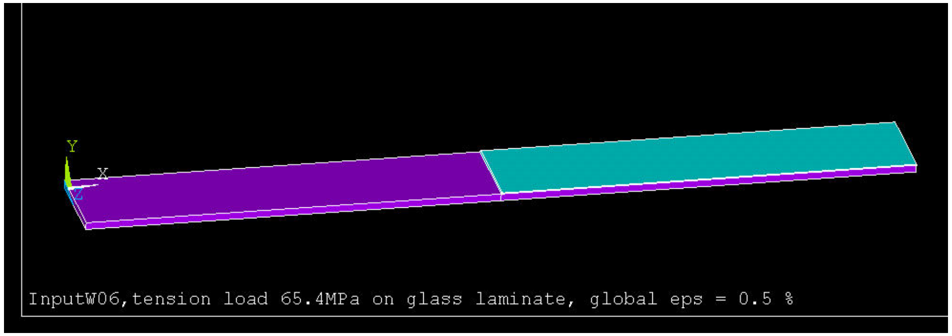


Figure 1 Geometry: Purple = laminate in glass-fiber/epoxy(0/+45/-45/0) with t1 = 1.79 mm, green = carbon-fiber/epox (+45-45) with t2 = 0.25 mm, total length = 200 mm, width = 20 mm. A global tension of 0.5%, a temperature load of -40°C and both temperature and tension load are applied.

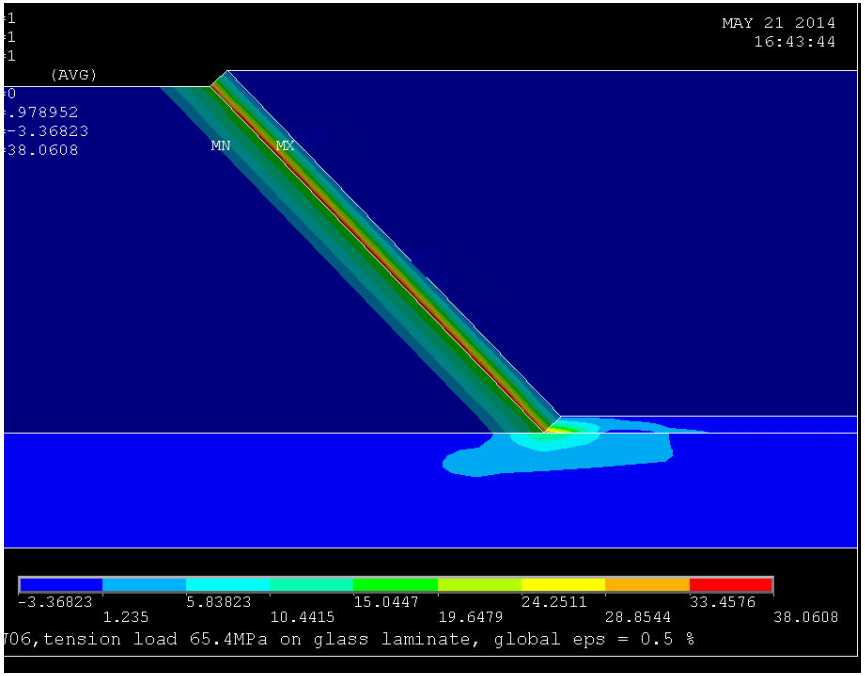
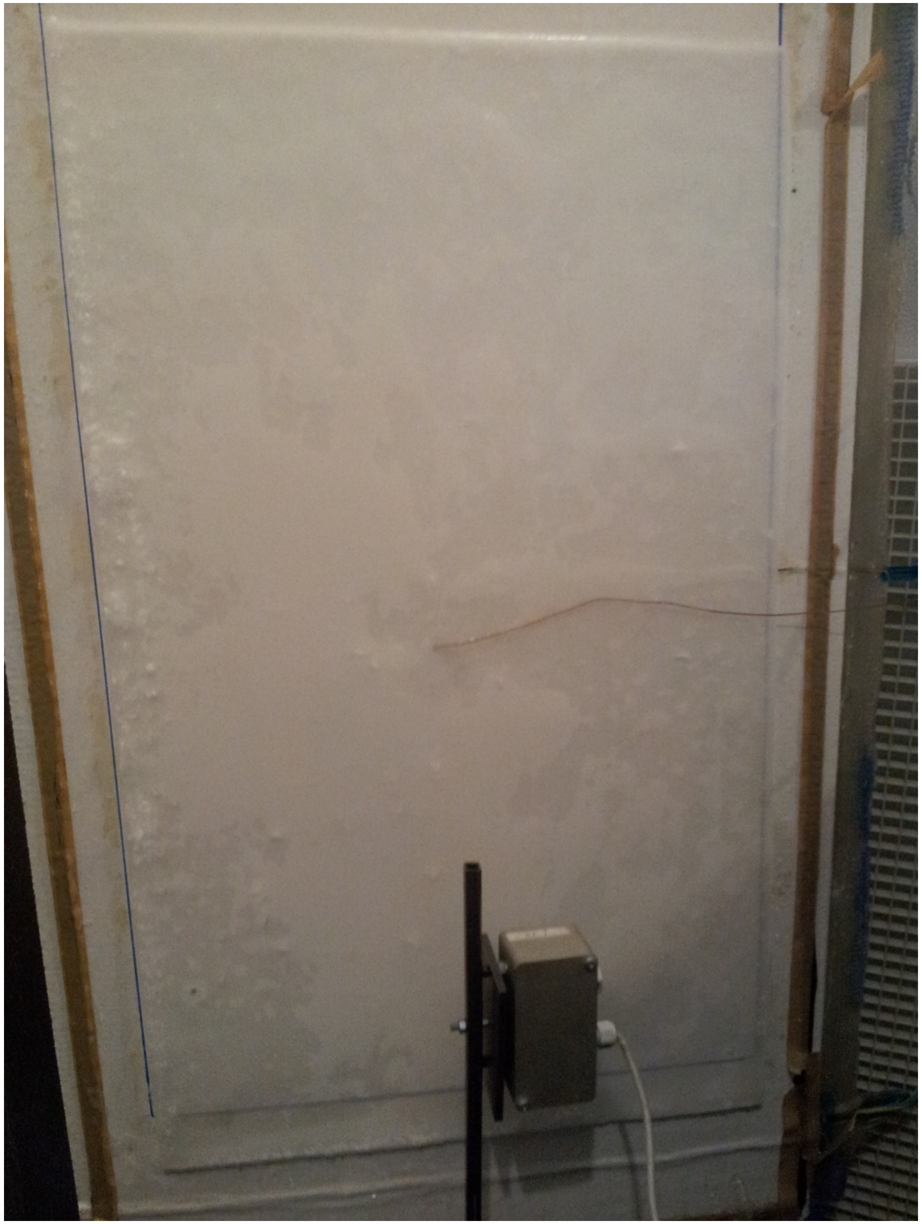


Figure 5 Example of results: Maximum shear, $\tau_{xy,max}$ = 38.1 MPa

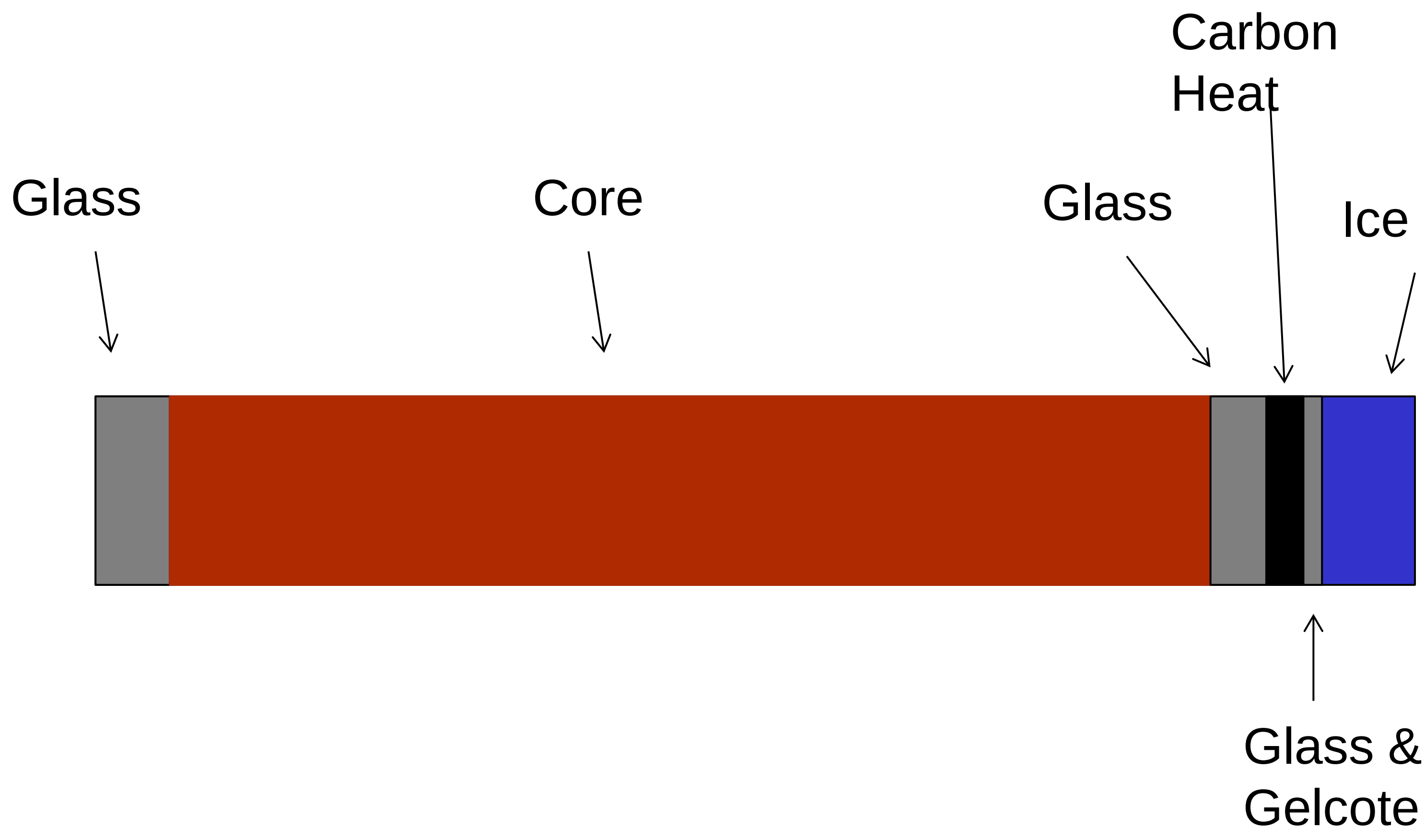
Note strain concentrations, lower strain and stress in real case

Experiments in climate room

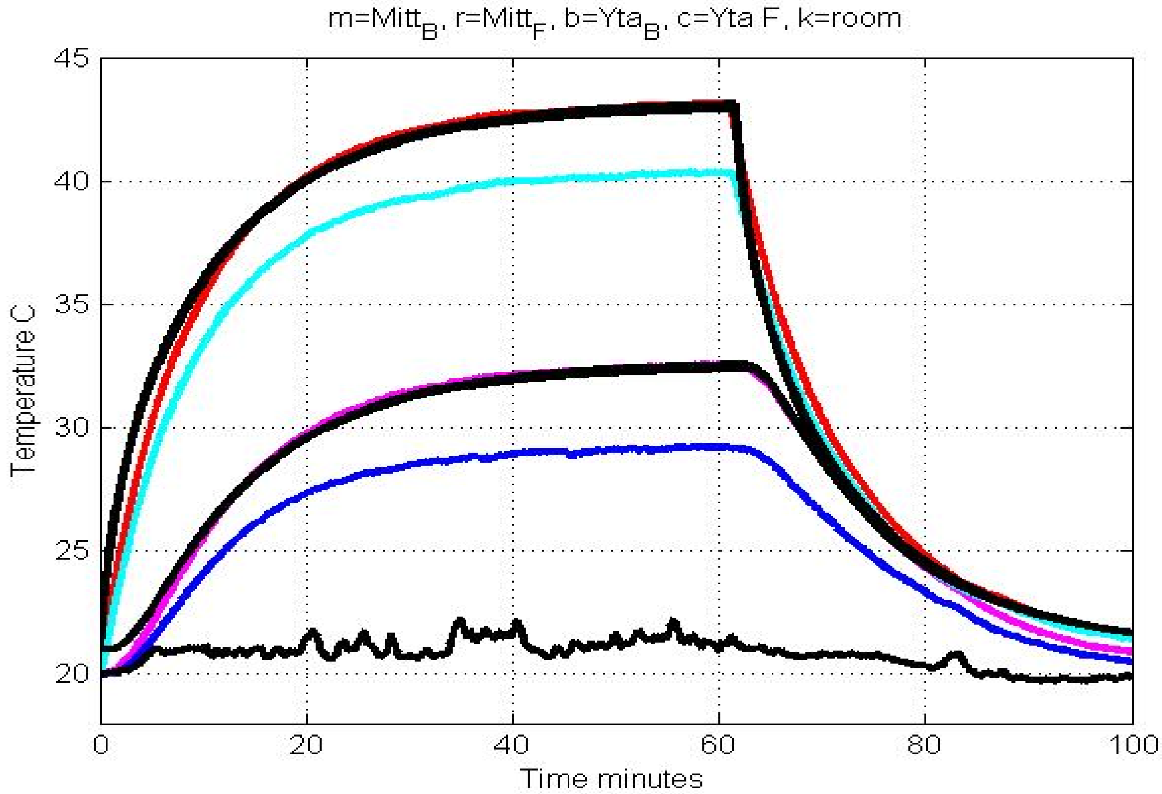


Final set-up

Simulation model



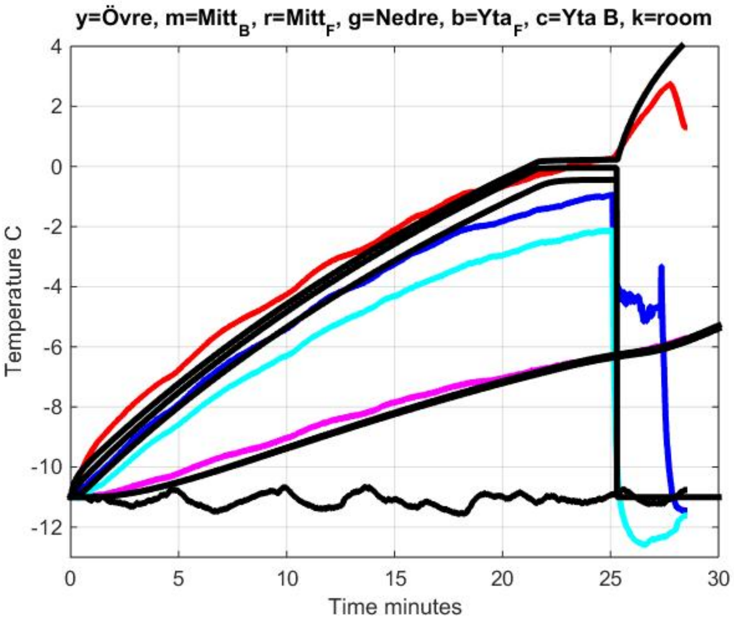
Results from simulations compared with measurements, No ice.



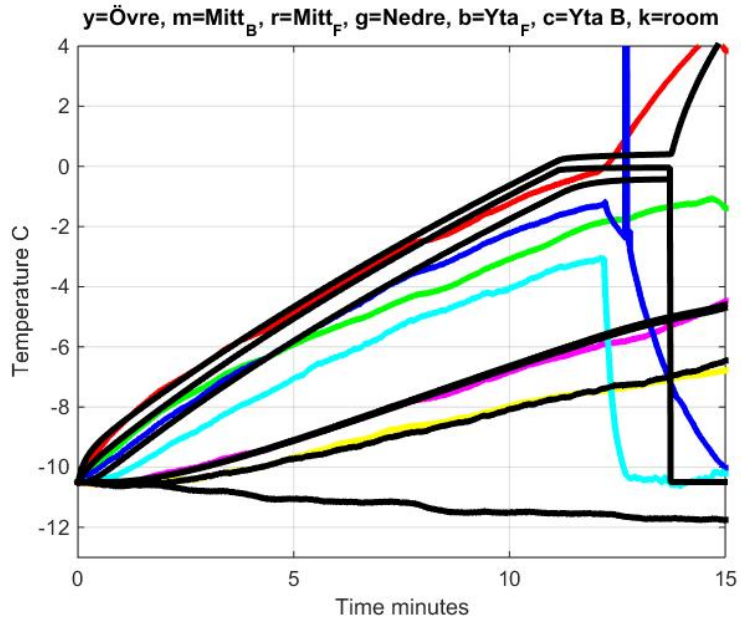
Measured temperature 1, measured temperature 2, simulation

Results from simulations compared with measurements, 5mm ice.

300 W/m^2



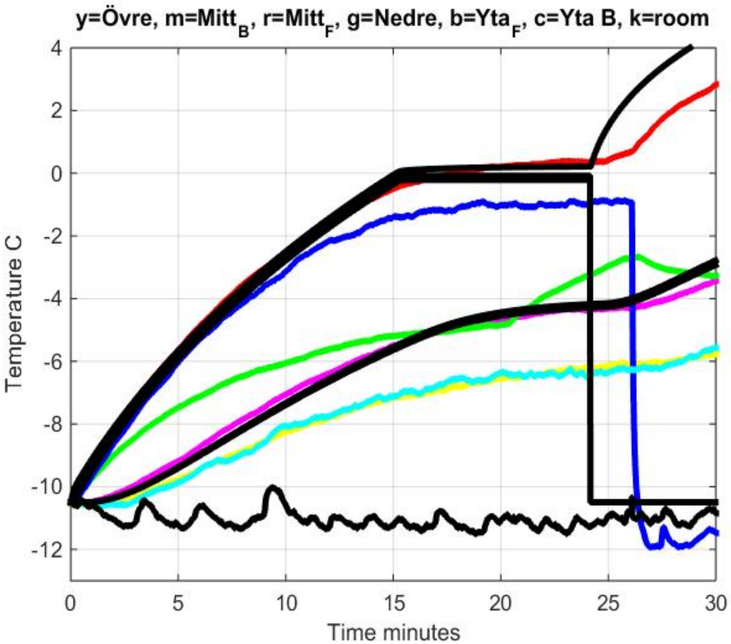
500 W/m^2



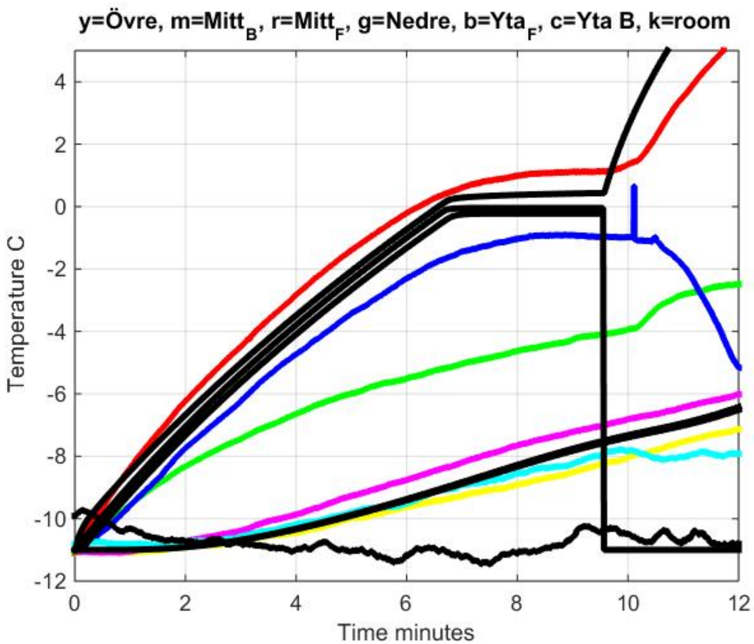
Measured core back, measured core front, measured ice interface, simulation

Results from simulations compared with measurements, 10mm ice.

300 W/m²



500 W/m²



Measured core back, measured core front, measured ice interface, simulation

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Results from simulations compared with measurements

For thin ice < 5mm an simulated water layer of 0.2mm is needed to explain the measurements

For thicker ice 10mm 0.1mm water layer correlate with experiments

Discussion
Simulation of ice is difficult
An ruff estimate is possible +- 10% in time is possible to estimate in simple load conditions.
From experiments it is indicated that less melting of ice is needed for higher loads.
In a real anti icing situation it is likely that ice throw occur short after the 0 temperature is reached in the interface between ice and the wing.

Measurements in Uljabuouda

Bild 6: Kontroll av bladvärmens funktion med hjälp av minihelikopter utrustad med värmekamera. Foto: Lars Liljenfeldt, Swerea SICOMP.

Questions