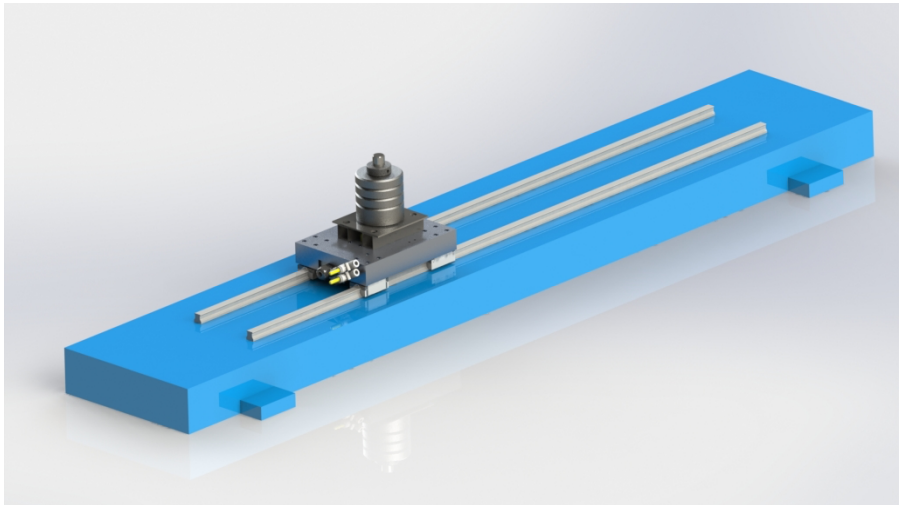


Simulation and Testing of Temperature Behavior in Flat Type Linear Motor Carrier

LinMot Group

Mehrdad Khodayari

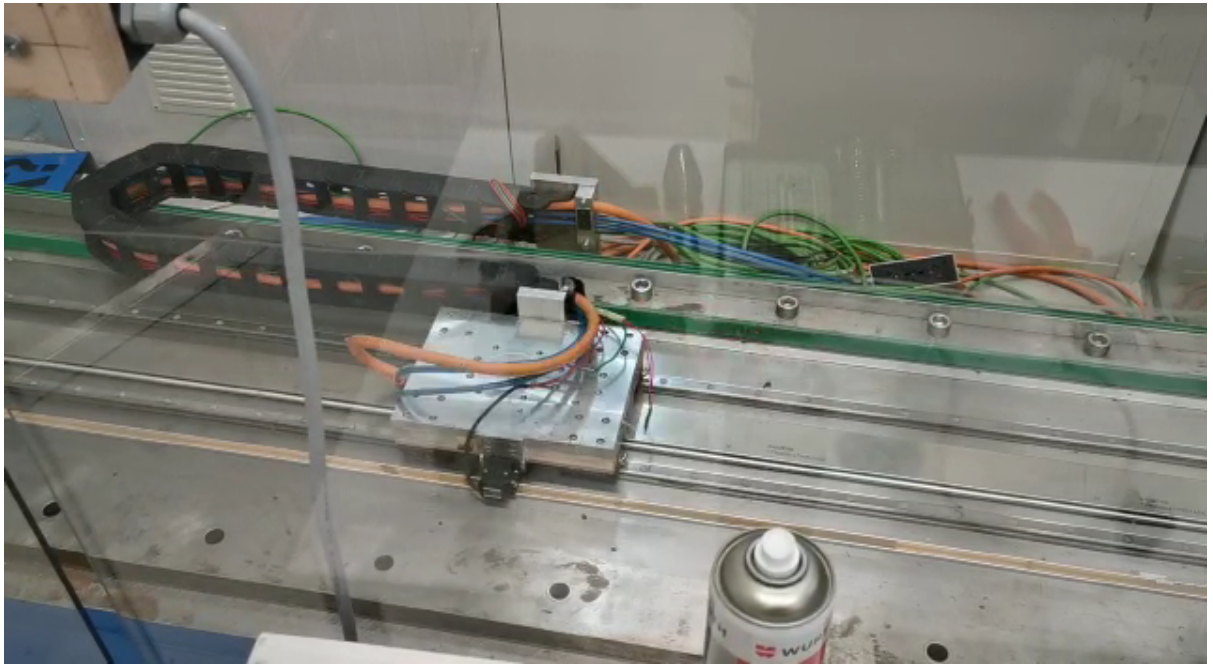
Robert Hermansson

Muhammad Usman

Kimmo Hirvonen

Motor moving in real life

Motor running with rapid movement*



*This cycle was not used in the experimental tests. It is just for presenting the motor in action.

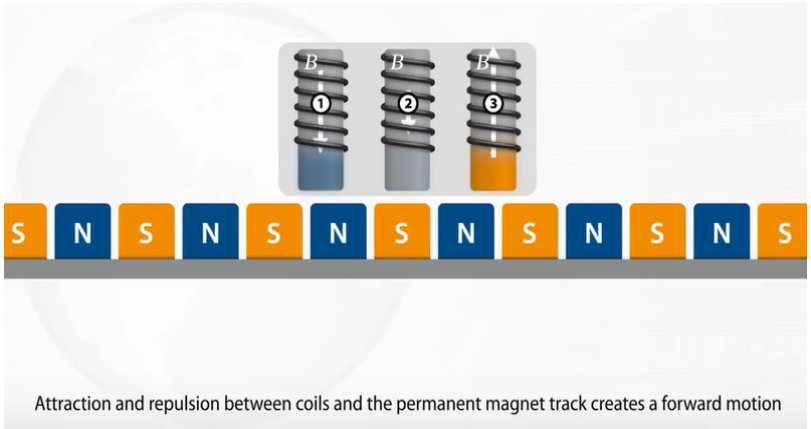
Siemens Linear Motor L-1FN3 with SINUMERIK Control

Working principle and Control

- The magnetic flux of coils and permanent magnets generate tangential and normal forces.
- Benefits: Fast, powerful and precise motor
- More sensitive to various force disturbances
- Driven by a PWM-modulated three-phase bridge
- Controlled with a standard SINUMERIK 840D sl CNC control

Purpose

- **Simulation and Testing of Temperature Behavior in Flat Type Linear Motor Carrier**



Attraction and repulsion between coils and the permanent magnet track creates a forward motion

https://www.youtube.com/watch?v=0_QBl6-_jJU

Research problem

- Problem of the linear motors is heat generation

  → Limits the performance, affects the accuracy

- Our research

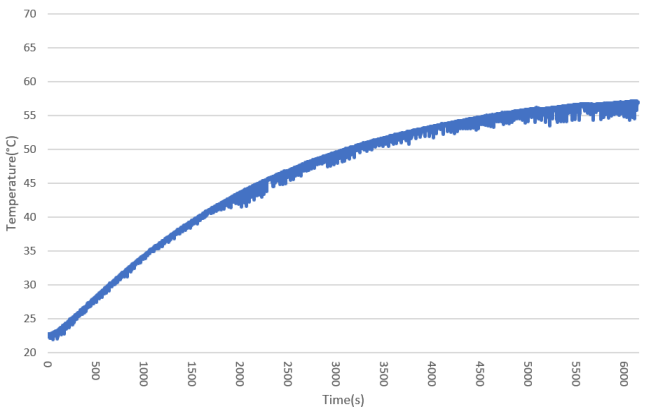
  → Test and Simulate the temperature behavior of Flat Type linear motor

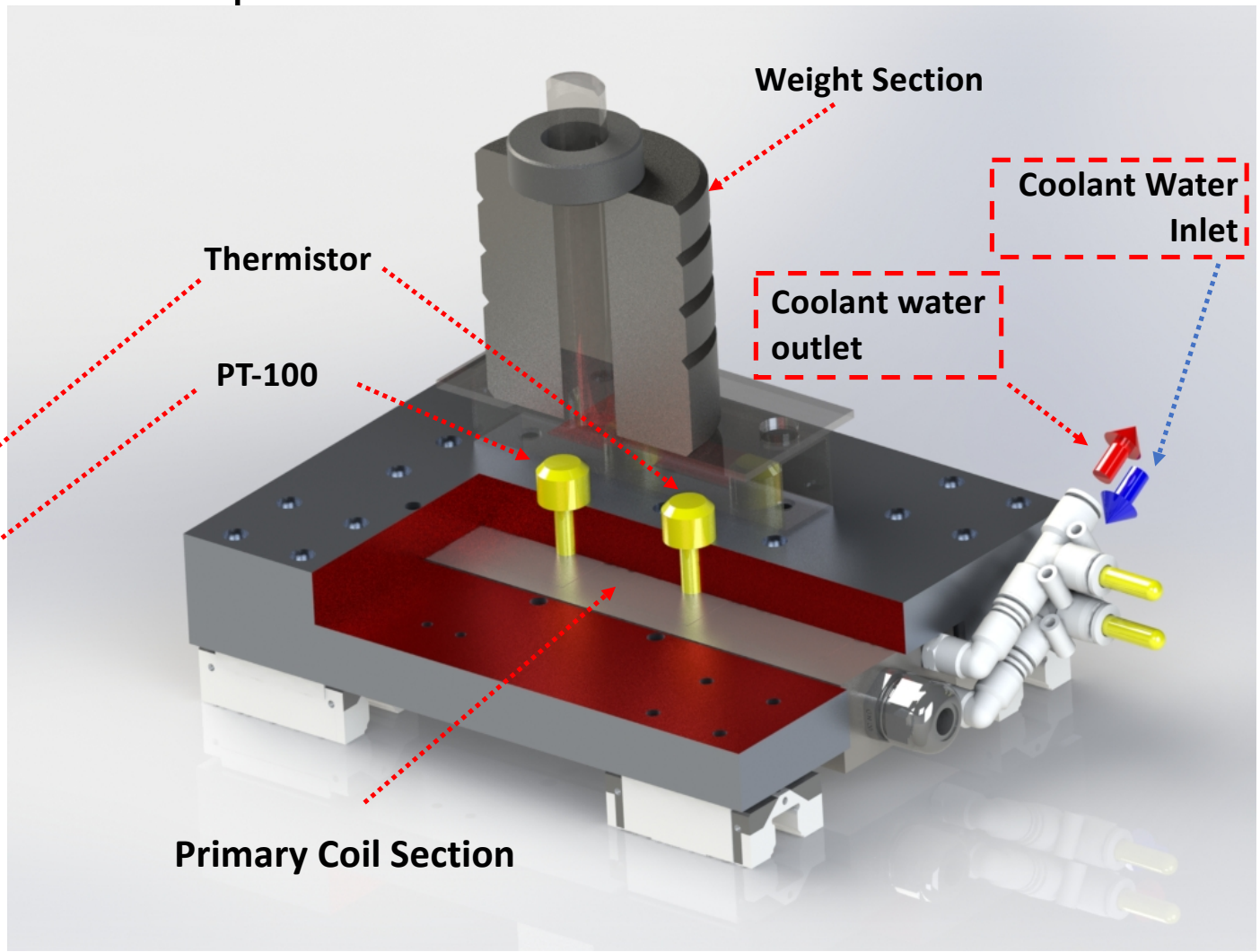
Results could be used for:

- Predict the temperature behavior of flat type linear motor in other applications
- Simulation model and methods could be used to study the temperature behavior in other similar type systems
- For further study of how different loads, working cycles and water-cooling system affect the temperature behavior

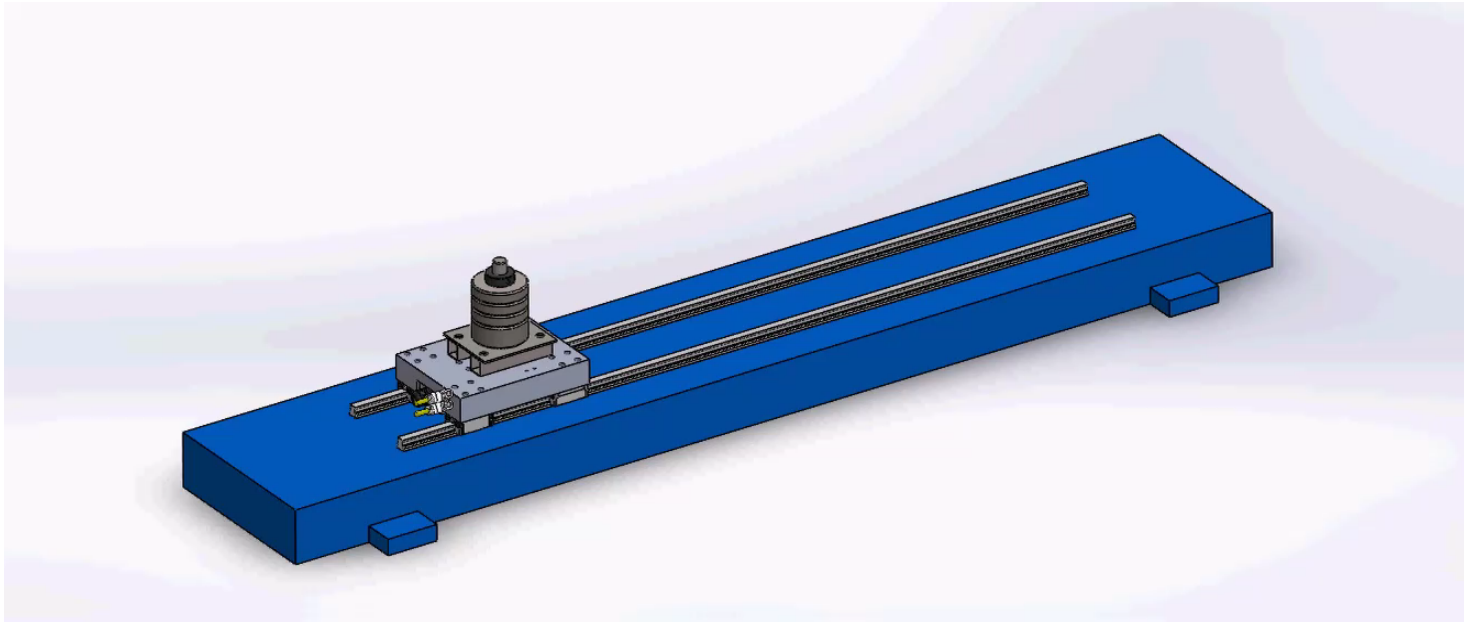
Methods for experimental research

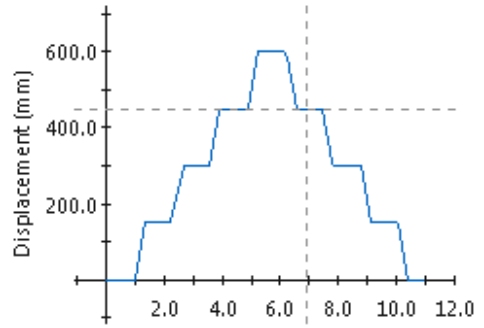
- Temperature measurement on top of the carriage
- External load added to the carriage
- Water cooling not used in our research

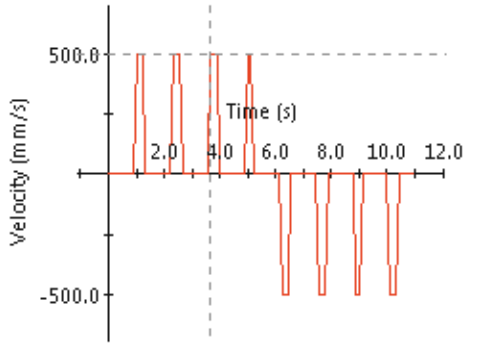




Duty cycle





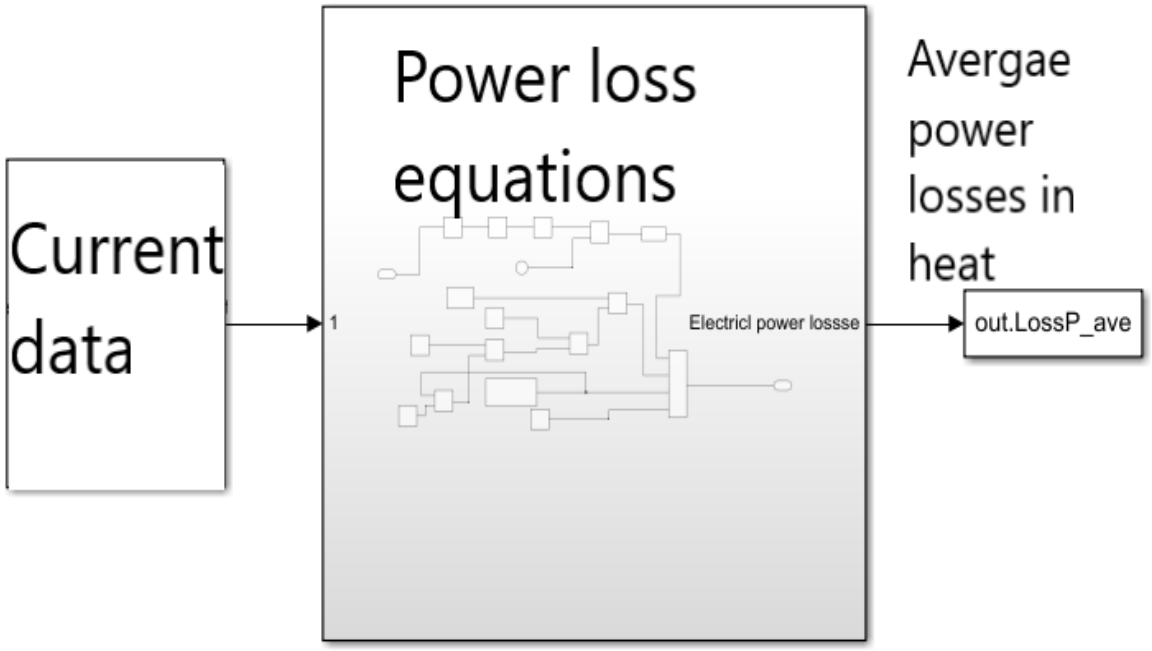


Displacement in each step:**150mm**

Velocity: **30 000 mm/min**

Acceleration: **30m/s^2**

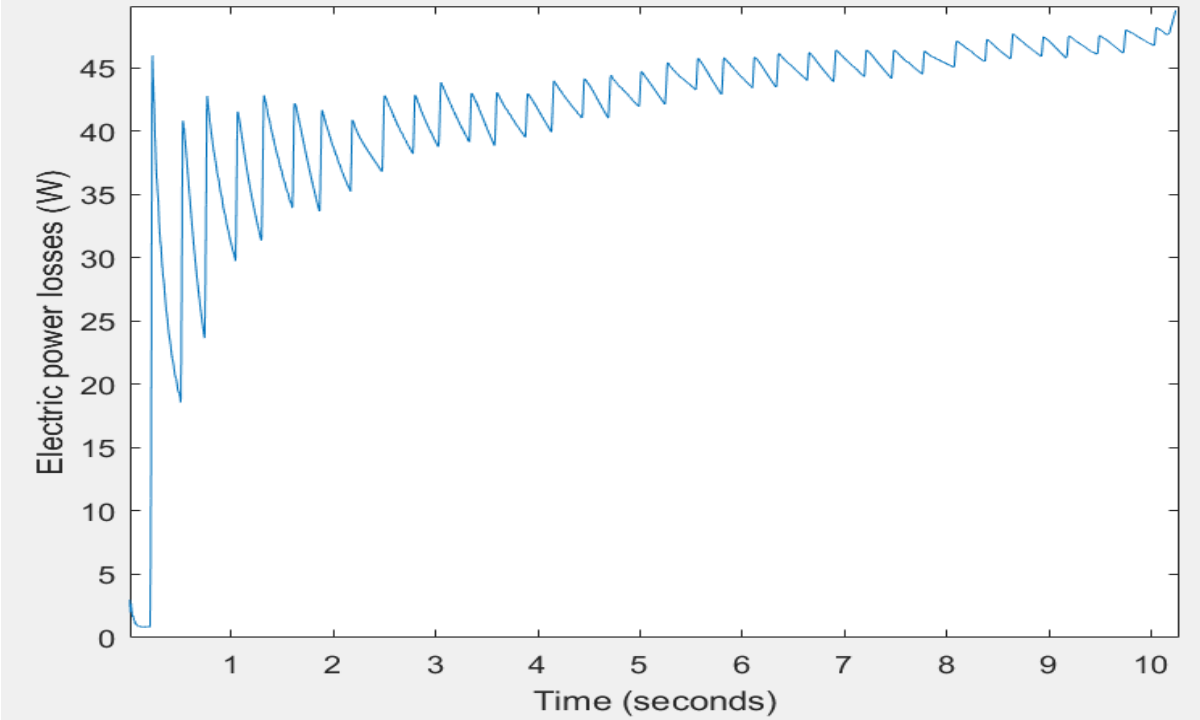
Simulation methods and results



A simple Simulink model consisting of power losses equations, which takes current data as input and outputs power losses to heat the motor coils.

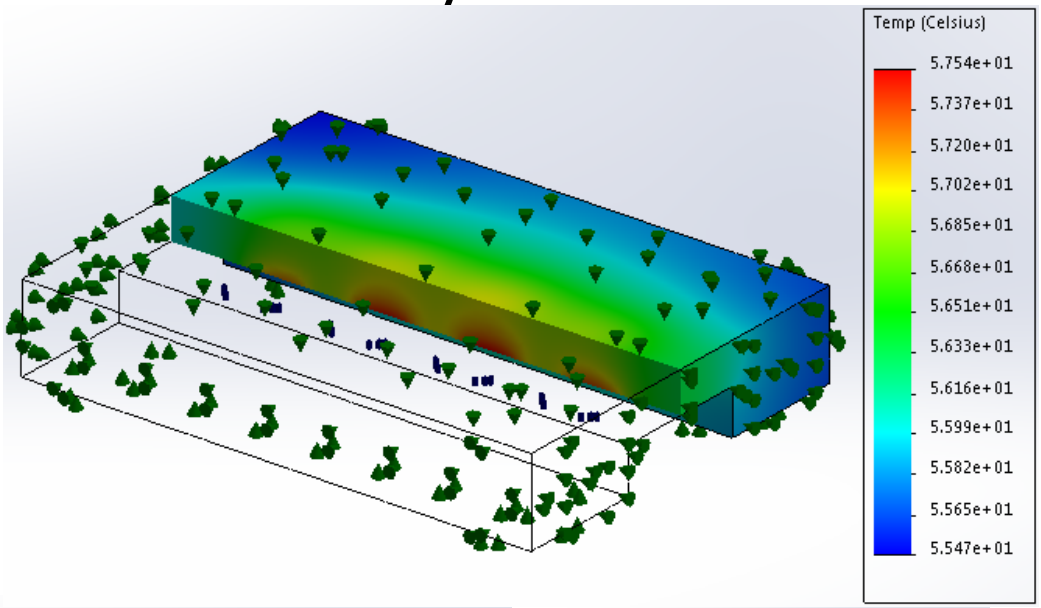
Simulation results

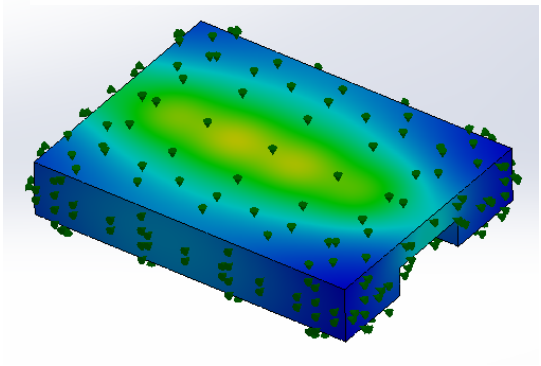
- Simulink average heat power loss =49.86 W

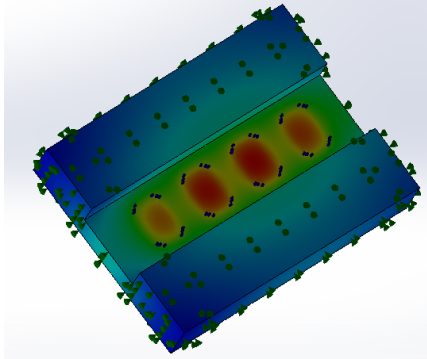


The graph shows the electric power losses with time in heating the coils.

FEM analysis and results





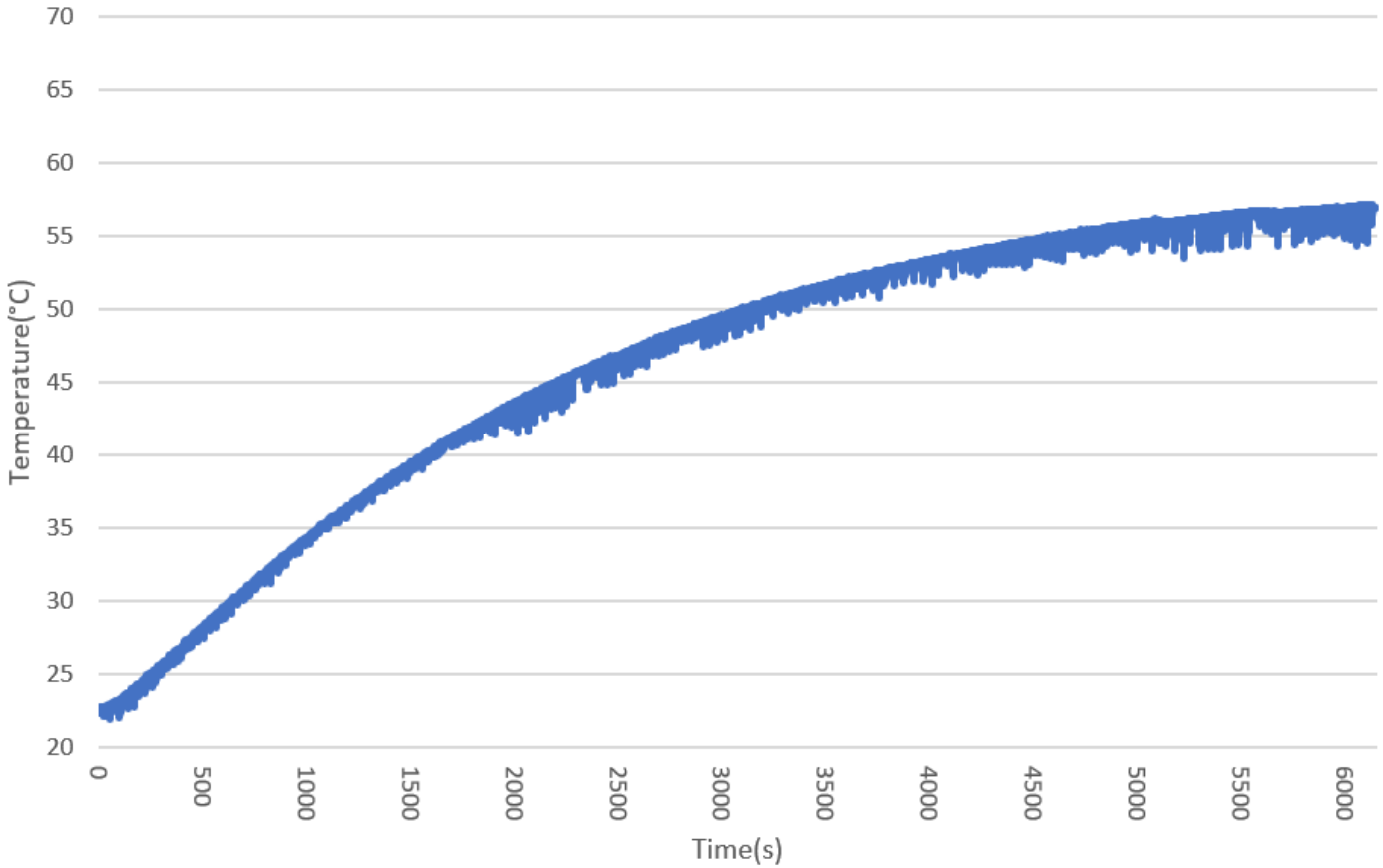


Steady state heat transfer FEM analysis with Solidworks:

- Heat power of 50 W applied to the carrier bottom surface
- Air convection coefficient of 11 $\frac{W}{m^2K}$ assumed for carrier surface

→ Temperature at the carrier surface reaches 57 ℃ maximum

Experimental results



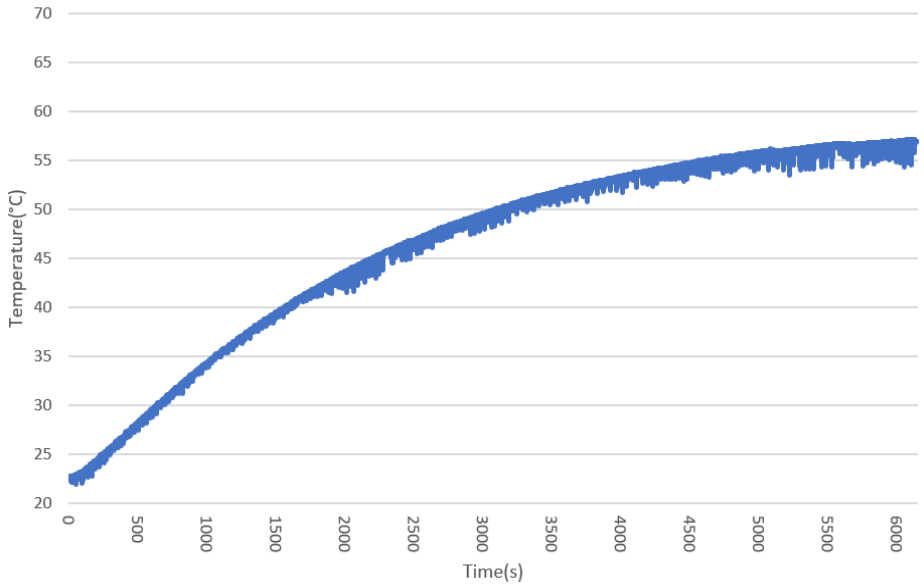
Continuous duty cycle:

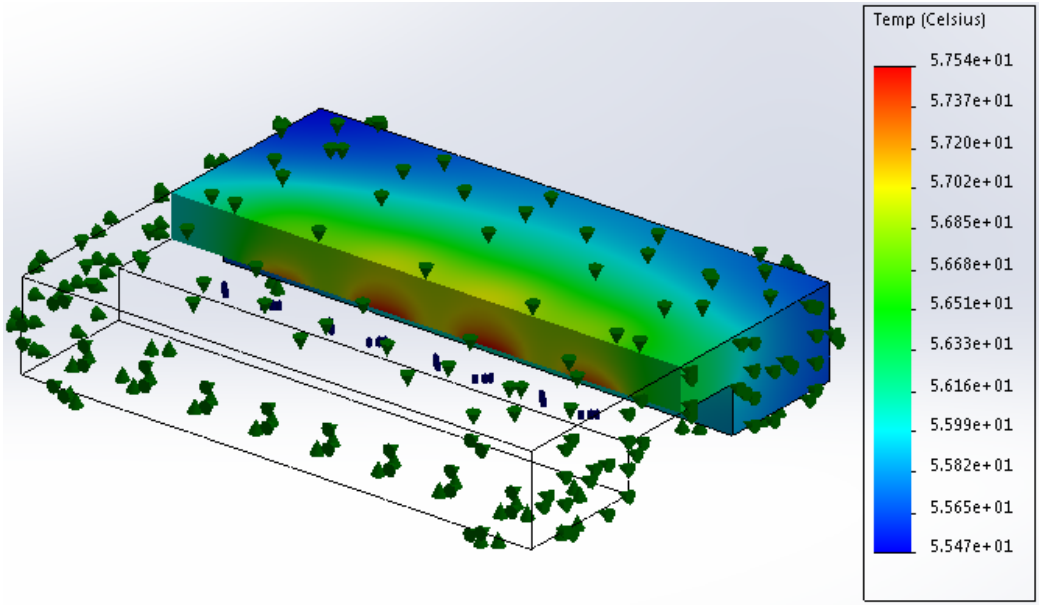
- Total mass 15.6 kg
- Velocity 30000 mm/min
- Acceleration 30 m/s^2
- 150 mm movements
- 0.2 s break between movements

Results

- Starting temperature 23 °C
- Final temperature 57 °C
- Cycle duration 1h 42min

Comparison of the experimental and simulation results





- Results are really close to each other with the maximum temperature of 57 ℃

Special thanks to:

Aalto University : Petri Kuosmanen and Panu Kiviluoma

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Heidenhein: Esa Härkönen