Cryogenic Heat Sink for Helium Gas Cooled Superconducting Power Devices

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Introduction

Superconducting power devices, such as cables, fault current limiters or transformers, need feedthroughs that connect them with other elements of the power system that stay at ambient temperature. The components at ambient cause a substantial heat influx to the superconducting device. A heat intercept, based on a heat sink, ensures that the superconducting device remains at the designed operating cryogenic temperature. It is critical in helium gas cooled superconducting devices because gaseous helium has significantly lower heat capacity compared to that of liquid nitrogen.

COMSOL Multiphysics was used to check the feasibility as well as an optimization tool for a copper heat sink.

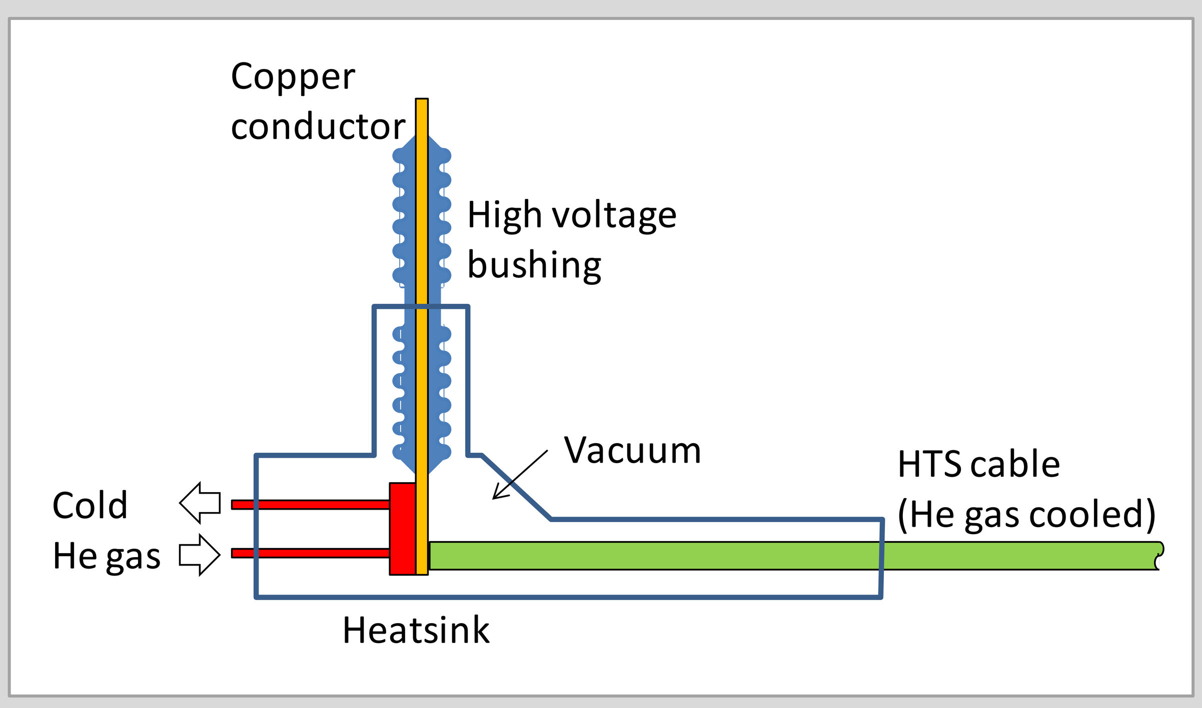

Figure 1. Schematic diagram of the cable termination with heat sink (red), HTS cable (green), and copper conductor (yellow)

Finite Element Models

A first finite element model was designed to determine the ideal number of fins for a given overall width of the base plate of the heat sink. A two dimensional steady-state model was implemented and allow to study the maximum surface temperature as a function of number of fins (Figure 2, 3).

A second finite element model determines pressure drop as a function of mass flow rate (Figure 4, 5) and temperature increase of the helium.

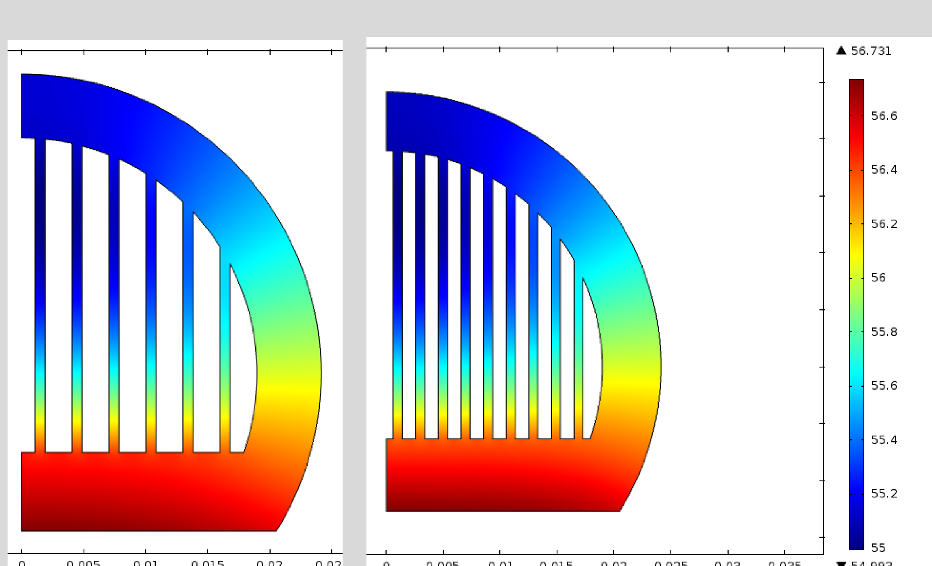

Figure 2. Surface temperature of the 2D model with 6 fins (left) and with 9 fins (right)

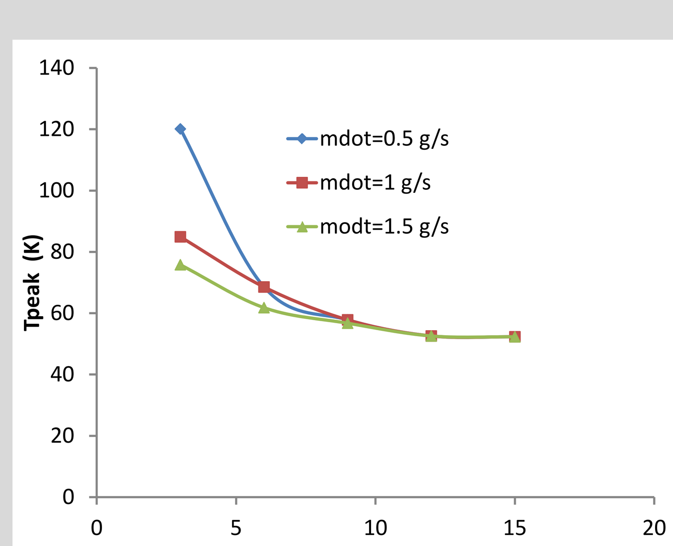

Figure 3. Maximum surface temperature as a function of number of fins and mass flow rate

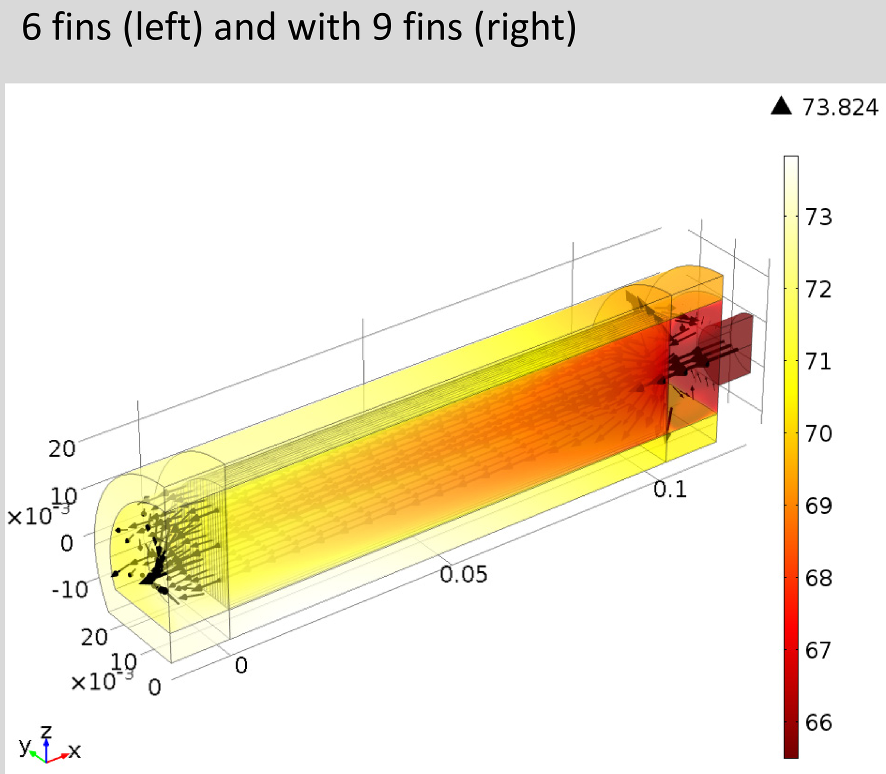

Figure 4. Surface temperature of the heat sink (in [K]) along with velocity field of the helium flow

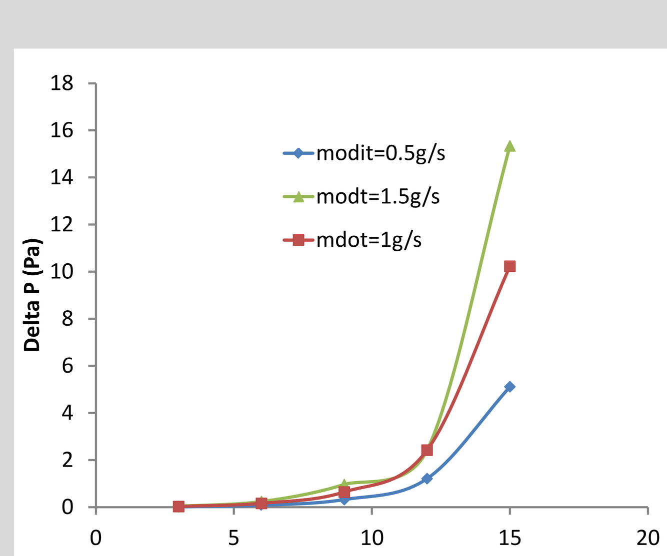

Figure 5. Pressure drop as a function of number of fins and mass flow rate

Experimental Validation

An experiment has been set up to validate the results obtained by simulation. The heat sink consists of four parts: The base block with fins, two end plates, and the tubular casing (Figure 6). Two copper tubes act as the inlet and outlet for cryogenic gaseous helium from the circulation system. A heater was attached to the flat surface (Figure 7).

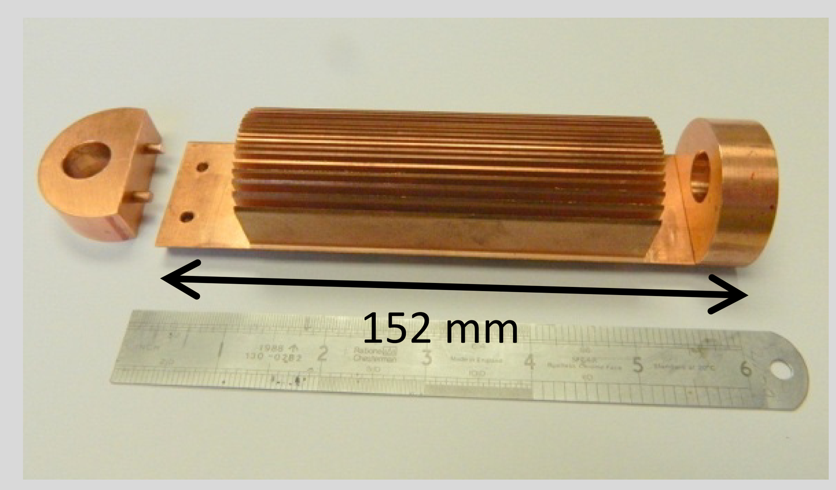

Figure 6. Parts of the heat sink before assembly through brazing

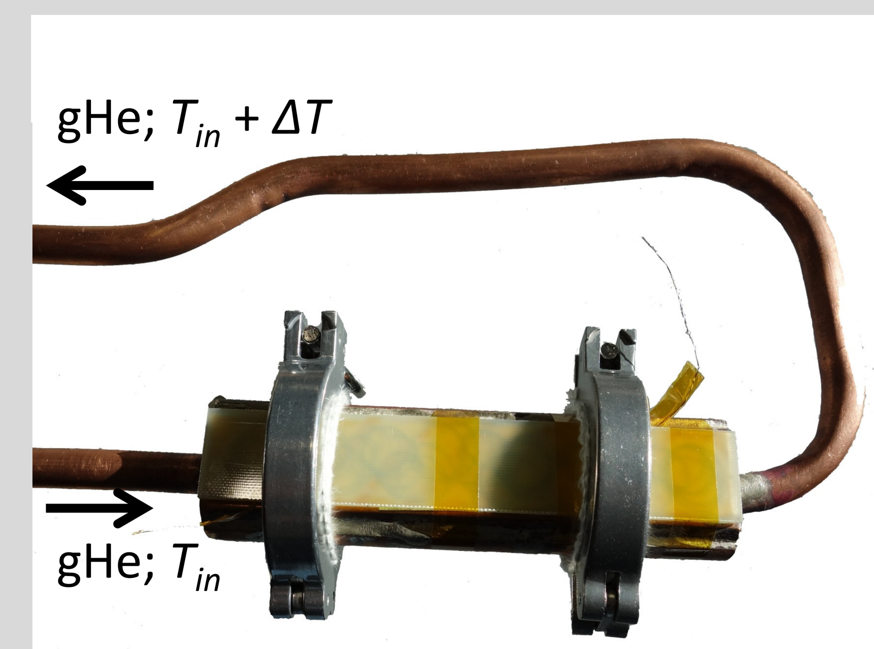

Figure 7. Heat sink complete with gas inlet, outlet, and heater before it was wrapped in Mylar radiation shield and inserted into the vacuum chamber

Table 1. Comparison of simulation results with measurements

	50 W		100 W	
Parameter	Model	Experiment	Model	Experiment
Temperature inlet [K]	58.6	58.6	65.5	65.5
Temperature increase [K]	4.15	4.7	6.45	7.3
Temp. heat sink [K]	63.0	77.3	73.8	84.0
Pressure drop [Pa]	284	294	313	297

Conclusions

- The proposed design of a copper heat sink is effective: It can meet the criteria for cooling efficiency, space restrictions, and pressure drop.
- The model in COMSOL Multiphysics is a useful tool for optimizing the geometry.
- Experimental data validate the finite element model.
- The model will be useful to design and optimize a heat sink for a supercon-ducting power cable and other power devices for shipboard applications.

Acknowledgement

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References

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