Thermomagnetic Siphoning on a Bundle of Current-Carrying Wires

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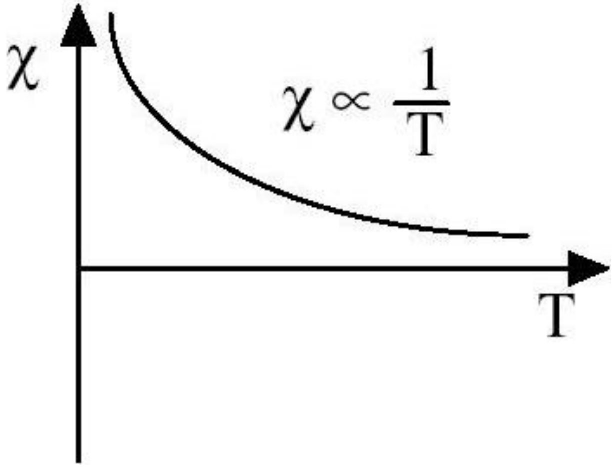
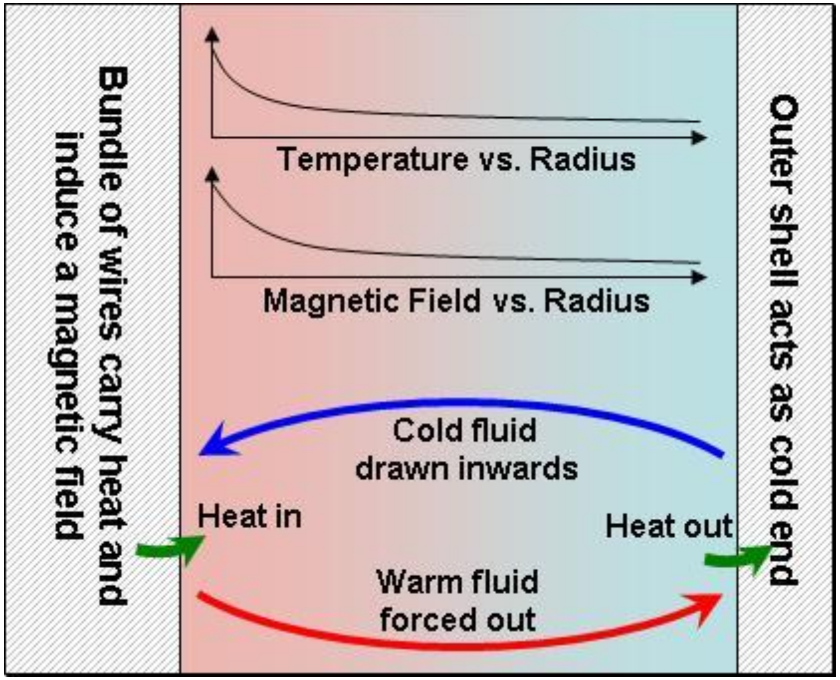
Overview

- Introduction
- Theory
- Use of COMSOL Multiphysics
- Results
- Conclusions
- Acknowledgements

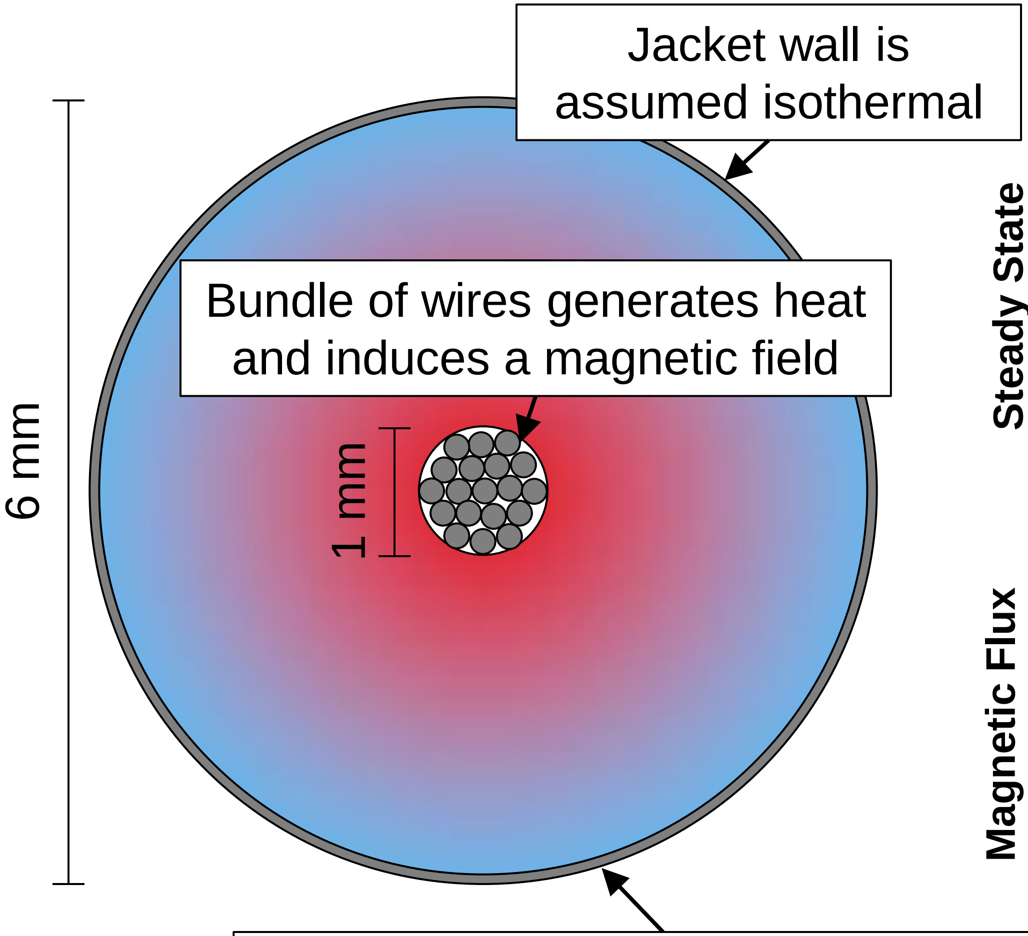
Introduction

- Thermomagnetic siphoning (TMS) uses differences in magnetic susceptibility to generate fluid motion
- The current study analyzes the temperature of a bundle of wires surrounded by a magnetorheological fluid (MRF) jacket





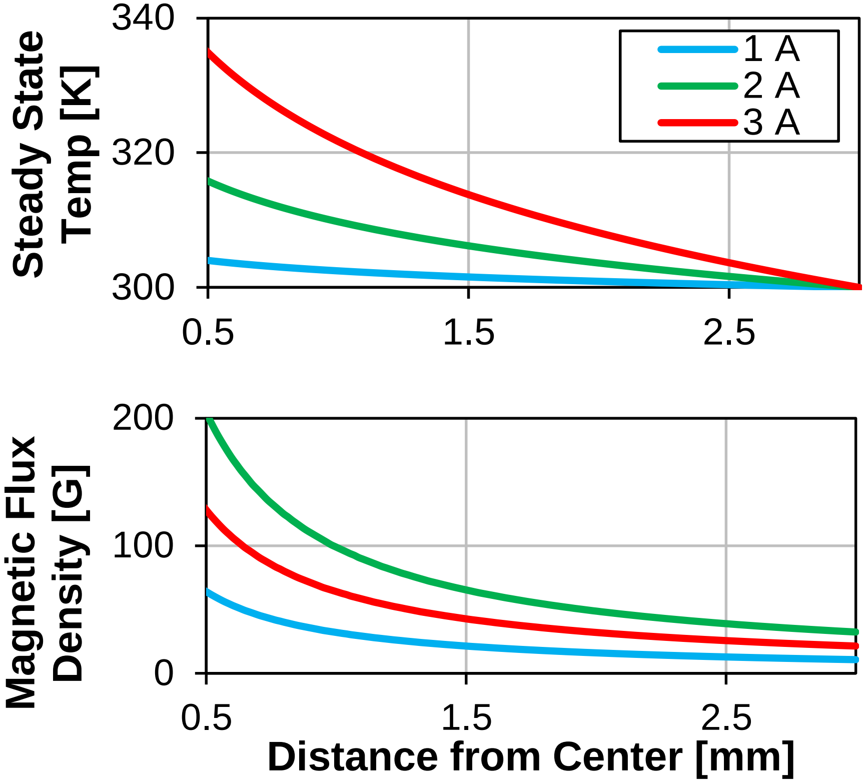
Problem Setup



Jacket wall is assumed isothermal

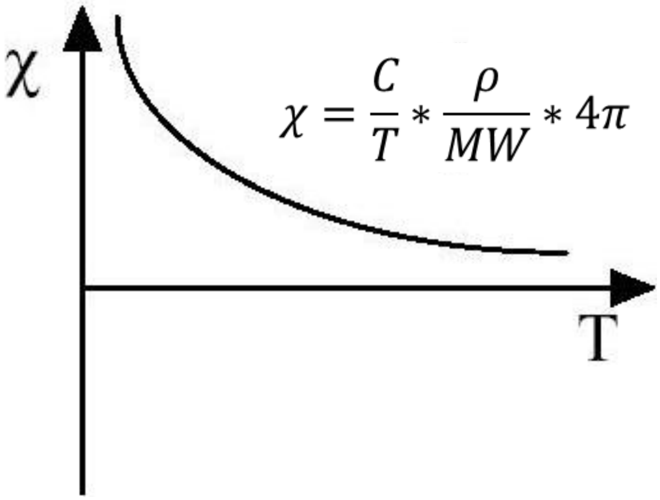
Bundle of wires generates heat and induces a magnetic field

Fluid jacket transports heat by conduction and/or convection if MRF

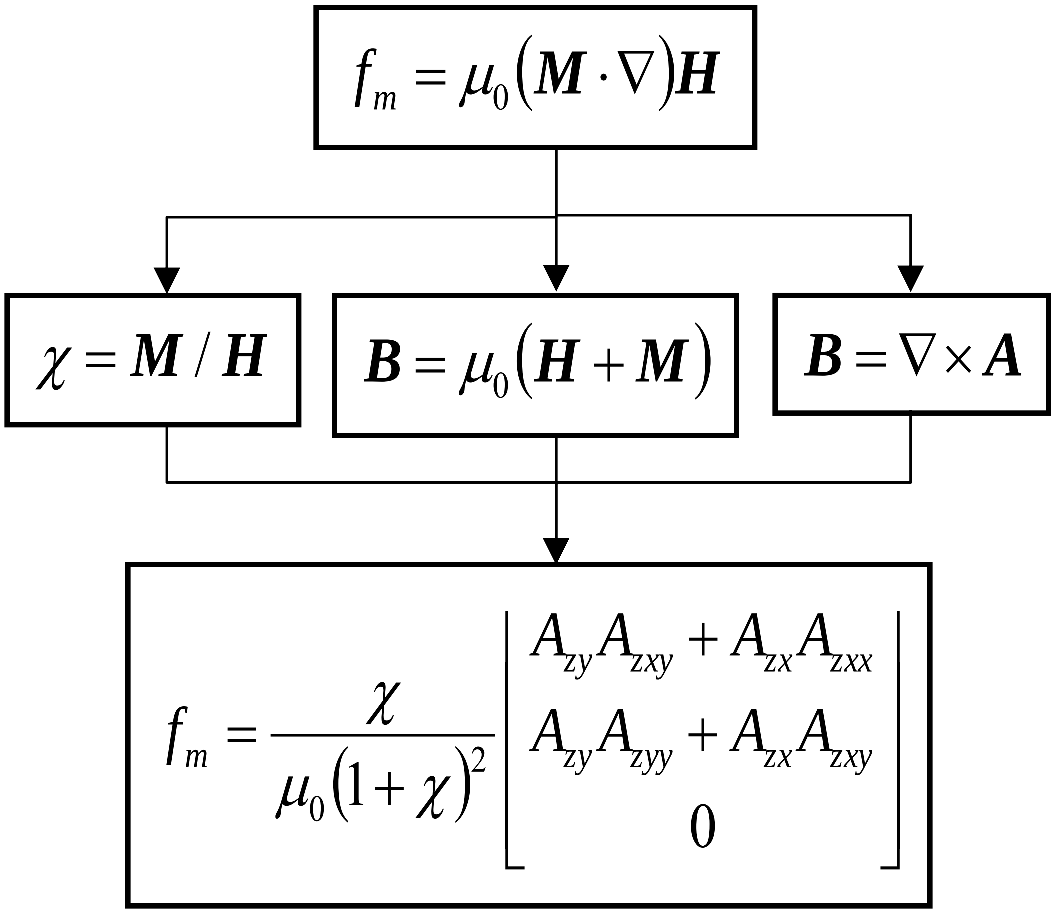


Theory

- Curie's Law dictates that magnetic susceptibility increases as temperature decreases



$$\chi = \frac{C}{T} * \frac{\rho}{MW} * 4\pi$$



$$f_m = \mu_0 (\boldsymbol{M} \cdot \nabla) \boldsymbol{H}$$

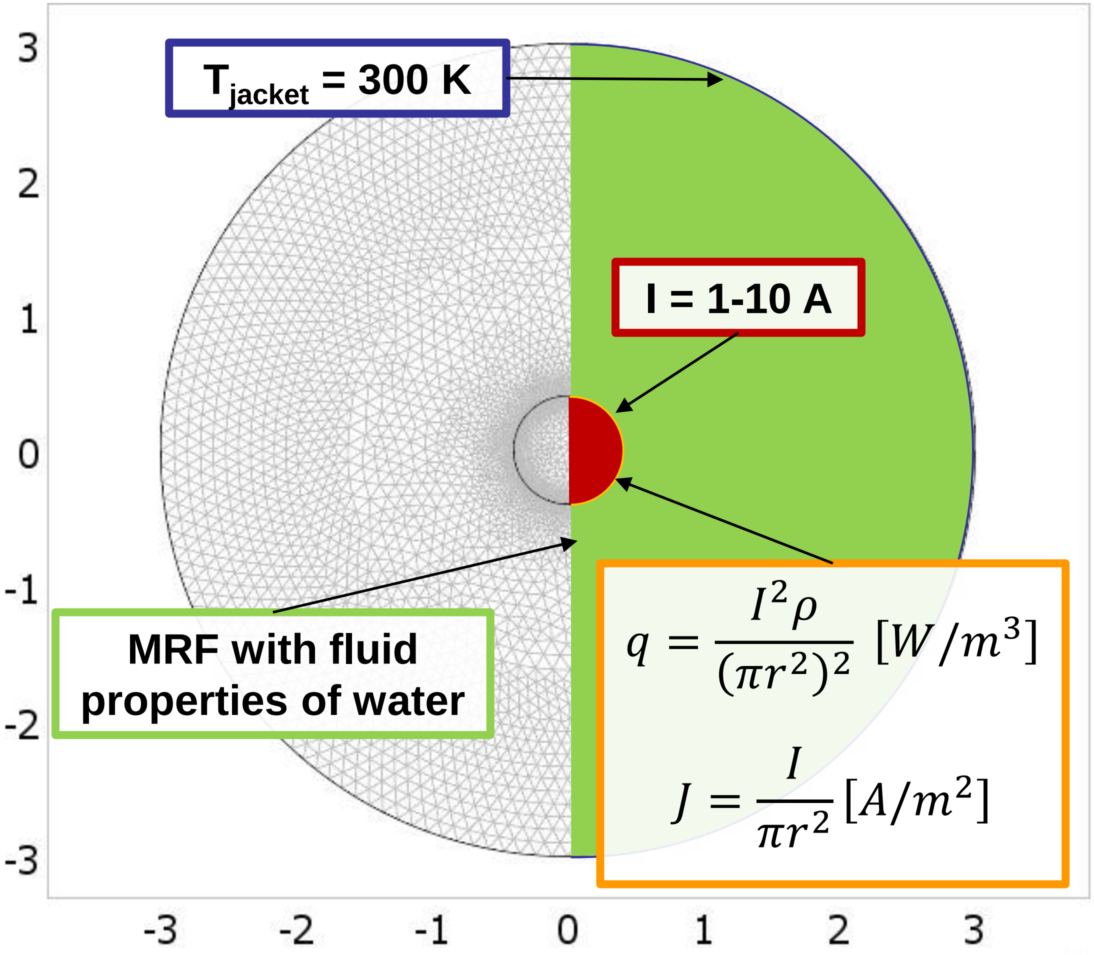
$$\chi = \boldsymbol{M} / \boldsymbol{H}$$

$$\boldsymbol{B} = \mu_0 (\boldsymbol{H} + \boldsymbol{M})$$

$$\boldsymbol{B} = \nabla \times \boldsymbol{A}$$

$$f_m = \frac{\chi}{\mu_0 (1+\chi)^2} \begin{bmatrix} A_{zy} A_{zxy} + A_{zx} A_{zxx} \\ A_{zy} A_{zyy} + A_{zx} A_{zxy} \\ 0 \end{bmatrix}$$

Use of COMSOL Multiphysics



T_{jacket} = 300 K

I = 1-10 A

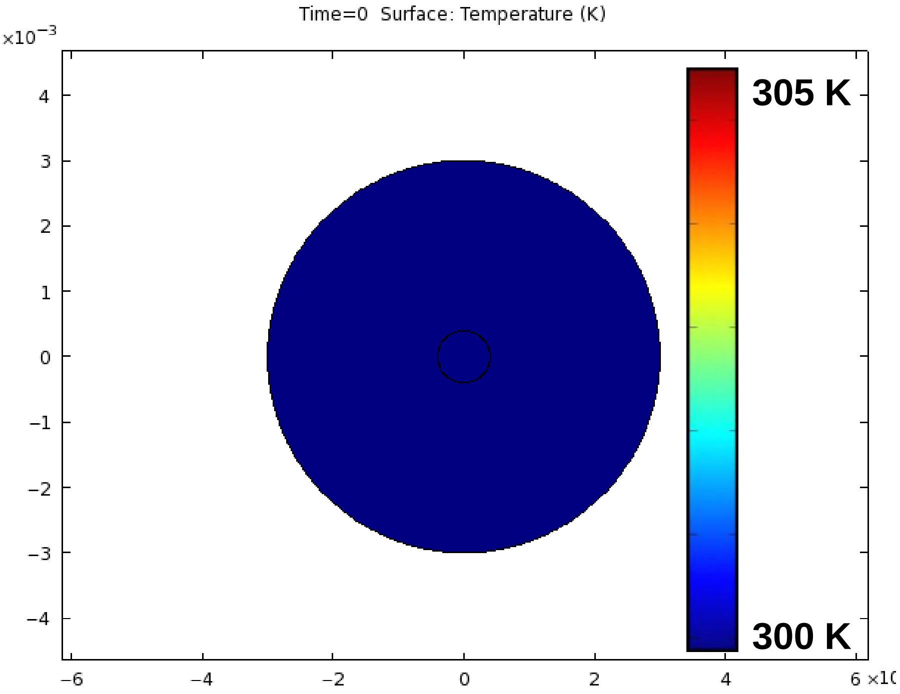
MRF with fluid properties of water

$$q = \frac{I^2 \rho}{(\pi r^2)^2}\ [W/m^3]$$

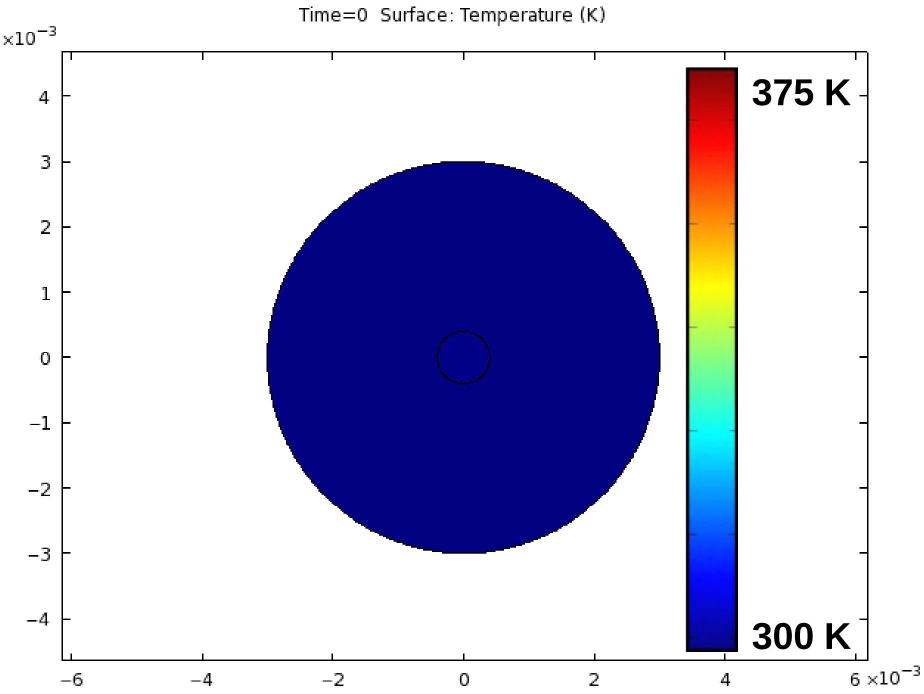
$$J = \frac{I}{\pi r^2}[A/m^2]$$

Mesh Type:	Advancing Triangle
# of DOF’s:	81593
# Elements:	10294
Min Element Qual.:	0.8326
Max Element Size:	1.47e-4
Min Element Size:	1.8e-5
Application Modes:	Magnetostatics
	Weakly Compressible Navier Stokes
	Convection and Conduction
Relative Tolerance:	0.001
Linear Solver:	PARDISO

Results

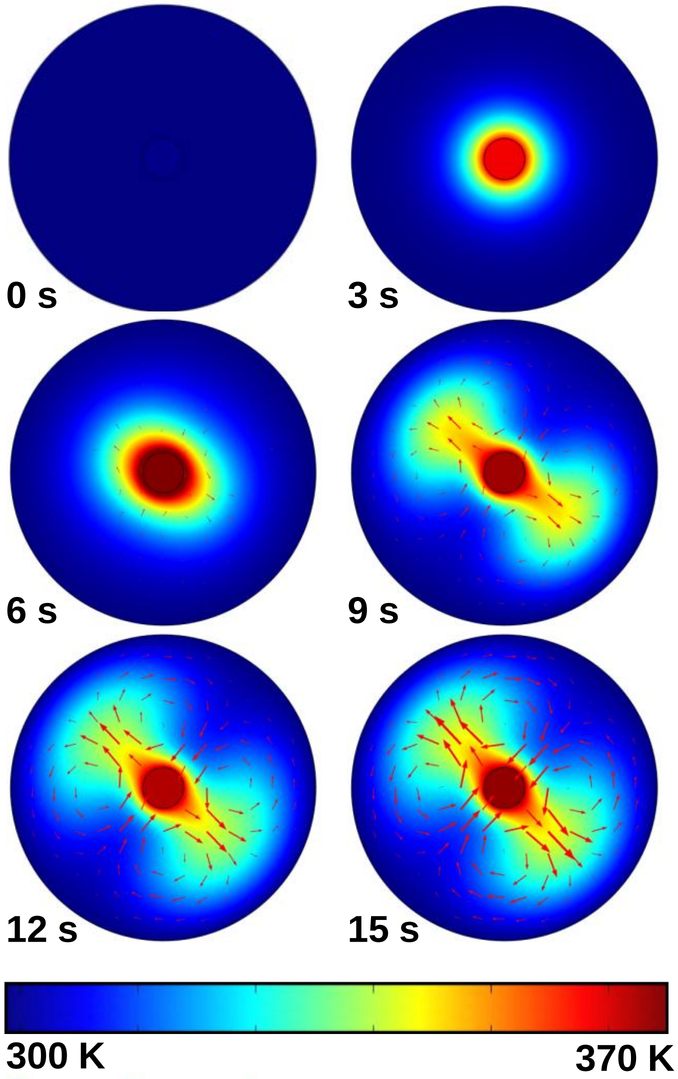


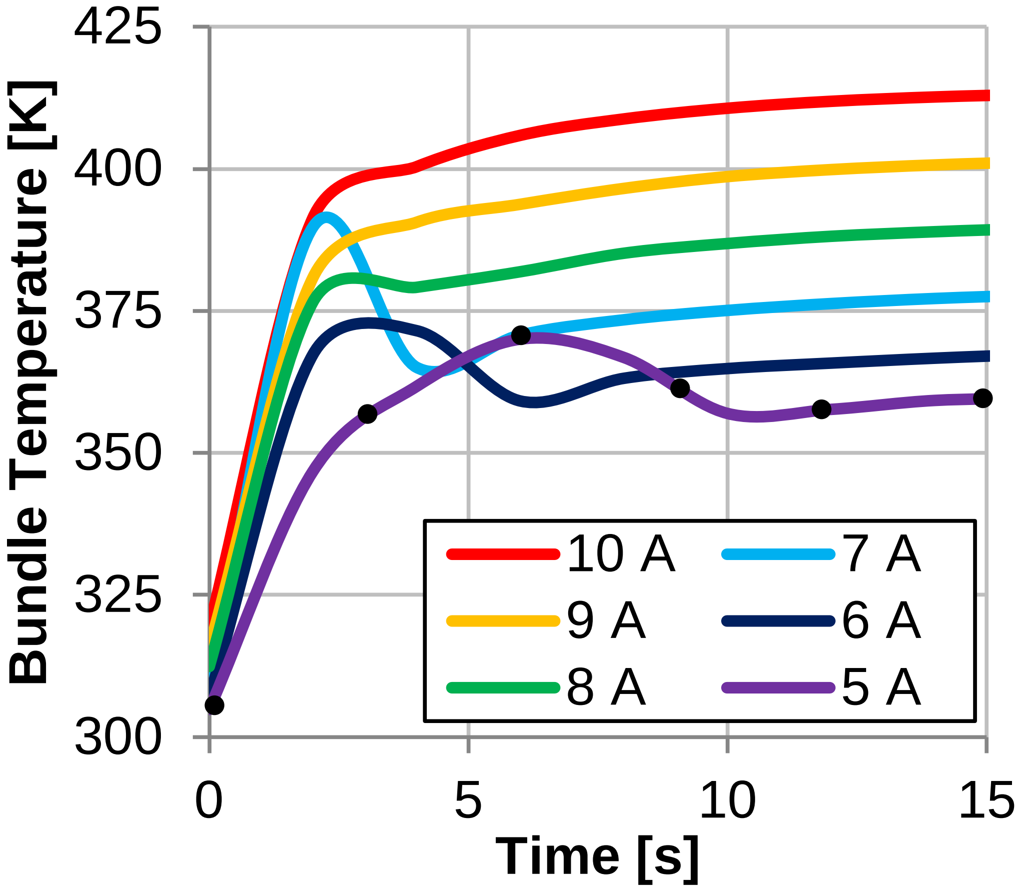
1 A
Conduction only



5 A
TMS

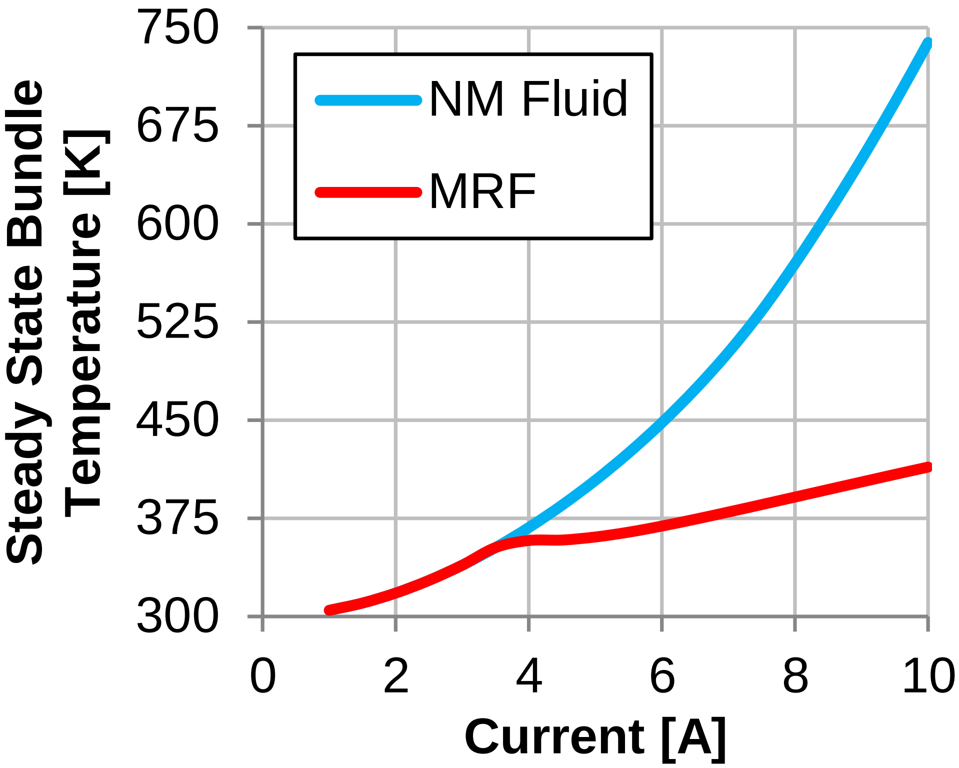
Results


0 s
3 s
6 s
9 s
12 s
15 s
300 K
370 K


Bundle Temperature [K]
425
400
375
350
325
300
0
5
10
15
Time [s]
10 A
7 A
9 A
6 A
8 A
5 A

Results

- As high currents induce greater temperatures and magnetic fields, TMS becomes increasingly effective.
- Disclaimer! The study did not factor:
  - Operability
  - Manufacturing
  - Affordability
  - Boiling
  - Electrostatic discharge



Conclusions

- TMS was studied for its cooling performance on a bundle of current-carrying wires using COMSOL Multiphysics 3.5a.
- The magnetic, thermal, and fluid equations were solved and compared a MRF versus a non-magnetic fluid.
- The benefits of TMS were shown through a significant reduction of the steady-state temperature
- Actual fabrication of a magnetic fluid jacket may negate any benefits due to additional cost and complexity

Acknowledgments

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  - Dr. Clair Batty
  - Mr. Bob Anderson