The Modelling and Design of an MRI-Compatible Cryosurgical Probe

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Motivation
• X-Ray mammography is the most common breast cancer imaging technique, but is 60% less effective when compared to MRI
• Combining MRI with cryosurgery could result in a more effective breast cancer treatment

Gas Mixture Properties
• Property data from REFPROP for various pressures
• Interpolation for properties using temperature and pressure
• Viscosity and conductivity calculated using the two-phase volume fraction

Gas Mixture Optimization:
• Optimized for the operating pressures and temperature range
• Maximum minimum isothermal enthalpy change \( \Rightarrow \) Results in the best cooling capacity

\[
0.6C_3H_8 + 0.36CH_4 + 0.04N_2
\]

Thermodynamic Modelling

Input Parameters:
\[N = 20 \quad D_{inner} = 1 \text{ mm} \quad D_{outer} = 2 \text{ mm} \]
\[P_{in} = 2000000 \text{ Pa} \quad P_{out} = 101325 \text{ Pa} \]
\[T_{h,in} = 293 \text{ K} \quad T_{h,out} = 190 \text{ K} \]

Results:
\[\dot{q}_{cool} = 10 \text{ W} \quad \dot{m} = 0.2 \text{ g/s} \quad L_{straight} = 49.2 \text{ in} \]
\[L_{helix} = 6.4 \text{ in} \]

Conclusions
With an optimized gas mixture, an MRI-compatible cryoprobe can deliver 10 W of cooling power at 170 K while remaining a reasonable size. Heat exchanger model includes two-phase flow correlations for mixtures.

Future Work:
• Optimize heat exchanger geometry
• Generate hydrocarbon-free optimized gas mixture