Fiber Bragg grating sensors for a mass flow determination in a rotating liquid neon cooling channel
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Background
Increasing market for High Temperature Superconducting (HTS) applications offers new perspectives due to advantages of HTS:

- High current carrying capacity combined with high efficiency
- Option of using other coolants than helium (e.g. Nitrogen @ 77 K, Neon @ 27 K or Hydrogen @ 21 K)
- Chance of improvement of generator efficiency about 0.5% with the use of HTS instead of conventional technologies

Objectives
- Which thermodynamic conditions are developing in a rotating cooling channel? How does the heat transport in the fluid take place?
- Based on literature study a model is created to simulate the thermobehavioral effect of a given rotating cooling device.
- Which measurement techniques can be applied to validate this model in a practical measurement? Crucial points therefore are: large momentum and forces, sensor installation, wiring, signal tapping, accuracy.

Theoretical Considerations

Model
- General assumptions
  - Input output, only at imperfection.
  - No radial heat transport along cooling channels through solid.
  - Mass transport in single space element (heat for small heat inputs).
  - Reversibility of processes.
  - Secondary flow neglected (e.g. due to Coriolis force).
  - Interaction into channels not considered.

Important properties of model
- Assumption for calculation of mass flow in outer channels: density difference of both arms towards periphery. Pressure difference, balanced by friction.
- Flow direction defined, not reversible.
- 2 thermal, induced mass flow system (modulated thermosensitivit: e) resistance to cold head.
- Transfer to rotor periphery.
- Flexible set of channel diameters.

Simulation Results

Basic result
- Large maximum pressure acting outer diameter $T_1 = 0.42m$.
- Inner bar at 95 bar (30 min).
- 135 degree (150 bar).
- 150 degree (75 bar).
- Ratio of mass flow rate cold head / cooling channel: $1 ... 2$.
- Channel diameter + pressure $\rightarrow 0.2 \cdot 3 \cdot 4 \cdot 5 ... 10$ mass flow rate $\rightarrow 0.2 \cdot 3 \cdot 4 \cdot 5 ... 10$.

Results with additional heat input for mass flow determination
- The temperature relations range $1.000 K ... 1.000 K$ accuracy. A high sensitivity of temperature measurement system required.
- Due to thermosensitivit of effective temperature increase leads to increase of mass flow rate, error created leastest with thin channels.

Study of bare and polymer coated FBG sensors

Study of metal embedded FBG sensors

Investigation of Fiber Bragg Gratings

Options for the mass flow measurement system
- Bose method for HTS heat transfer measurement
- Hot wire method: very good absolute measurement accuracy
- Reference method: very high measurement resolution and time response

Investigation of mechanical property and sensor survivability for high speed rotation
- Study of embedded metal FBG sensors
- Study of metal coated FBG sensors

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