Status of DCLL MHD Experiments and near future plans

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Outline

**Manifold Experiment Status**
Flow distribution in poloidal channels and pressure drop reduction

**Flow Channel Insert and Heat Transfer Experimental Plans**
- Effectiveness of FCI as electric and thermal insulator
- Flow structure and heat transport properties in the presence of natural and forced convection in rectangular channels with FCI
The Manifold Experiment: problem definition

1- Can we achieve a ‘uniform’ flow distribution?
2- How?
3- How large is the ‘uniform flow distribution’ operating window? (how much are the min and max allowable flow rate in each channel?)

For a given inlet velocity and B-field, the flow rate in each channel depends on:
- velocity/pressure distribution in the expanded region (determined by the geometry and the electrical boundary conditions)
- pressure drop in each channel
- outlet flow conditions (outlet manifold)

In order to answer these questions we need first to understand what are the features of this type of flows
The Manifold Experiment: guiding ideas

Simplified geometry that captures the essential physics

- Only one expansion in the field lines direction (no expansion in the direction perpendicular to B)

- 3 parallel channels of $30 \times 20 \times 320$ mm each and two expansion/contraction elements of equal aspect ratio (25 to 100mm in the field lines direction)
Total size: $800 \times 120 \times 30$ mm

Relevant parameters

- TBM: $B=4$ T, $L=0.2$ m (half channel width), $U=0.1$ m/s
  $\rightarrow H_a=10^4$, $R_e=10^5$
- Exp: $B=1.7$ T, $L=0.05$ m, $U_{\text{max}}=0.2$ m/s
  $\rightarrow H_a=3 \cdot 10^3$, $R_e_{\text{max}}=10^5$

Similarity based on $H_a^2/Re$ (or $H_a/Re$)

- 2 identical test articles except for the wall conductivity:
  - test article with non conducting walls
  - test article with conducting walls except for the parallel channels
The Manifold Experiment: guiding ideas

Comparative study between these two cases will help answer the following questions:

1- Is the FCI really needed in 3d elements (expansion, contraction) to reduce the pressure drop?

MHD flows in 3d elements are associated with additional pressure drop caused by axial electric currents that do not (or partially) close their paths in the walls.

<table>
<thead>
<tr>
<th>Cross section</th>
<th>Small</th>
<th>Large</th>
</tr>
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<tbody>
<tr>
<td>Average velocity</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Electric potential</td>
<td>High</td>
<td>Low</td>
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The Manifold Experiment: guiding ideas

2- How the velocity distribution looks like in the expansion region with and without the FCI and what is the corresponding flow distribution for different flow regimes (Ha, Re)?

3- How can we achieve a uniform flow distribution (optimization)?
   Passive way
   - find an optimum geometry for the expanded region (FCI?):
     One could think of breaking the central jet by using transverse ribs. Since the upper and lower jets are confined in regions close the side walls, the rib thickness does not need to exceed 1 or 2 cm

   - MHD coupling between channels by allowing induced currents to cross from one channel to another. This can be achieved by substituting the first 20-30 cm of SiC/SiC FCI with a stainless steel FCI (where temperature is still not too high). This will also increase the pressure drop in the channels. This idea seems promising because this balancing effect will (in theory) dynamically adapts or adjusts itself to the flow conditions. To what extent this will be effective? We do not know yet

optimum geometry and MHD coupling can be combined
The Manifold Experiment: guiding ideas

Active way
- Each channel will have a pair of electrodes (attached to the inner surface of the FCI side walls) that will be used as a local conduction-like MHD pump. The flow rate will be measured by another pair of smaller electrodes (EM flowmeter).

- Any flow unbalance detected by the EM could be corrected by ‘pumping’ more liquid where needed by applying electric currents (the magnetic field is ‘provided’)
  Static pressure (1m height of Pb-Li) will require using high currents (even with B=4T), which means high section cables…

- These local pump could also be used to create ‘artificial’ pressure drop by pumping in the opposite direction of the flow. In these case, the electric current should be relatively lower
EM conduction-like pump

Pressure taps

Measured quantities
- flow rate in inlet channel + in each sub-channel
- pressure differences (side walls and Ha-walls)
- electric potential distributions (side walls and Ha-walls)
- velocity distribution (Ultrasonic Doppler Velocimetry)

Experimental parameters
B-field intensity (Ha), mean inlet velocity (Re), wall cond
General view of the integrated Gallium loop
Details of the conduction pump and the test channel
test loop in the BOB magnet
Schedule

1st Experiment (non conducting walls)
Now in construction
March 07: preliminary tests. First results expected around end of march
April 07: Data analysis and first conclusions. benchmarking with ongoing numerical simulations
June 07: end

2nd Experiment (partially conducting walls)
April 07: decision about construction details (stainless steel test article + insulting paint where needed, or three different parts?)
June 07: start
August 07: end

3rd Experiment: optimization
Provide final conclusions and recommendations for an effective manifold design
December 07: end
Flow Channel Insert and Heat Transfer Experiment

- Effectiveness of FCI as electric and thermal insulator
Parametric study done by S. Smolentsev shows how both electrical and thermal conductivity of SiC may affect the bulk and gap flows and therefore heat leakage into Helium. However there is, in the real TBM (or in a real experiment), some uncertainties concerning the electrical and thermal contact between the liquid and the FCI that might result from a poor wetting. This important issue should be addressed.

- Flow structure and heat transport properties in the presence of natural and forced convection in rectangular channels with FCI
Suggestions to FCI/Heat Transfer Experiment

- forces on the FCI
- heat losses into water
- flow rates in the gaps/bulk
- velocity distribution