MHD Experimental Activities at UCLA

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Overview

Completed work

- o Flow distribution in a 3-channel Manifold

Current work

- o MHD Mixed Convection and Anisotropy level quantification Experiments

Diagnostics development

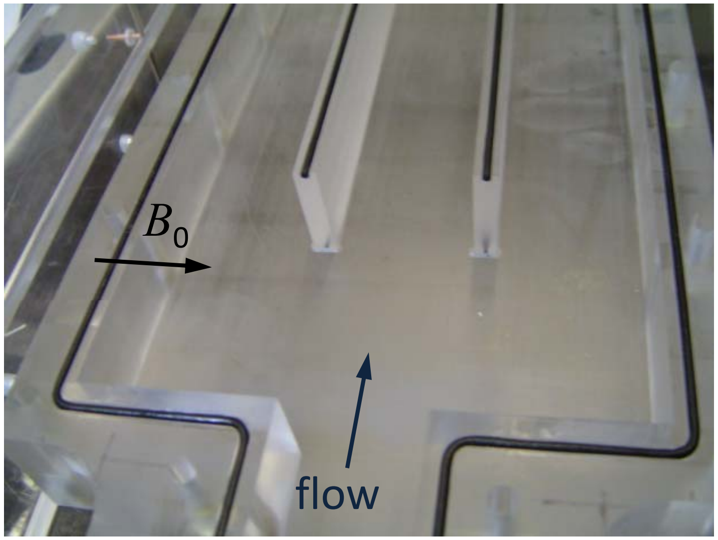
- o Ultrasound-based velocity measurements in liquid metals

Completed work

Completed work: flow distribution in a 3-channel manifold

Liquid metal flow is supplied by a single channel that expands abruptly in the magnetic field lines into a larger channel. The flow is then distributed to the parallel sub-channels

All channel are made out of acrylic to simulate the insulating property of SiC (or any other insulating coating)

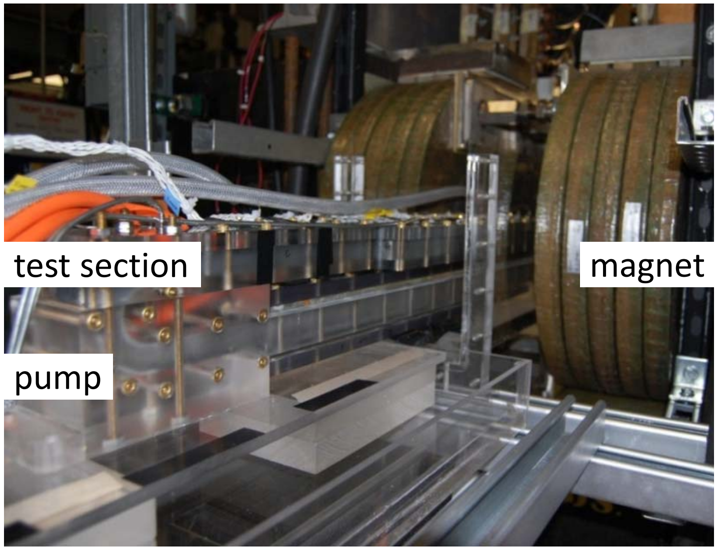


Experiment's non-dimensional parameters:

Reynolds number: Re $\equiv$ inertia/viscous

Hartmann number: Ha^2 $\equiv$ electromagnetic/viscous

Interaction parameter: N = Ha^2/ Re



regimes are covered. Note that the actual values of the field intensities at the electrodes were measured in order to accurately derive the mean velocities in each channel.

For relatively high interaction parameters ($N > 90$), the flow rates in all channels are found to be almost identical, thus N-independent. For $N \leq 90$,

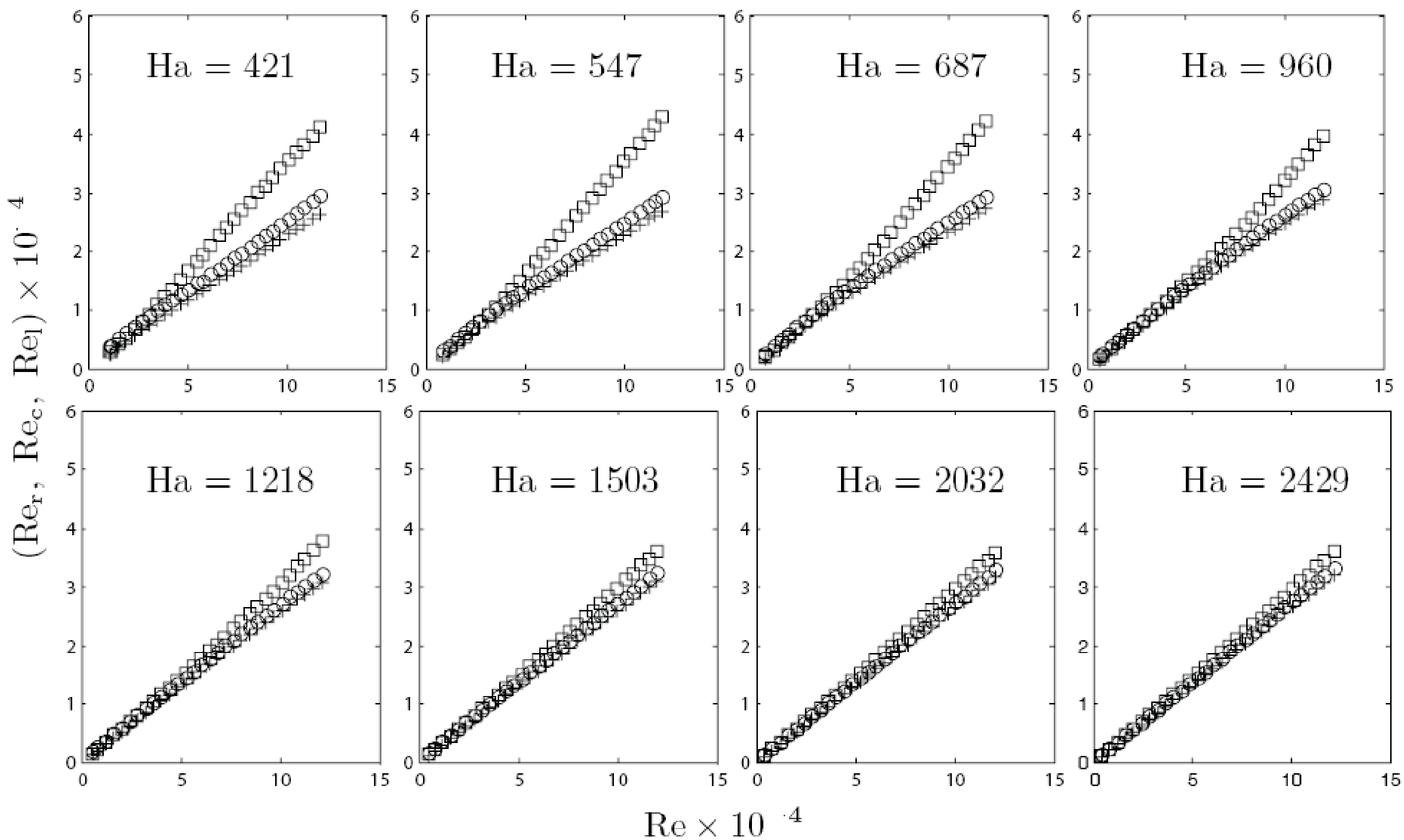


Fig. 3. Evolution of $\mathrm{Re_r}$, $\mathrm{Re_c}$ and $\mathrm{Re_l}$ versus Re for different values of Ha. '+' Left channel, '□' central channel, '○' right channel.

For $N \leq 90$, flow imbalance scales as N^{-m} (m=1/3 or 1/4)

For $N > 90$, flow imbalance is N–independent!

Completed work: flow distribution in a 3-channel manifold

We have demonstrated that nearly uniform flow rates of liquid metal can be enforced among parallel channels through a two-dimensionalisation mechanism providing that:

- A ‘sufficiently strong’ magnetic field is applied
- The liquid is electrically decoupled from the surrounding structure

MHD forces are taken advantage of in order to achieve a uniform flow distribution among the sub-channels!

Mechanism responsible for the two-dimensionalisation

Eq. of motion and induction

$$\frac{\mathrm{d}u}{\mathrm{d}t} = -\frac{1}{\rho}\nabla p + \nu\Delta u + \frac{B_0}{\mu\rho}\frac{\partial b}{\partial x_{//}},$$

$$B_0\frac{\partial u}{\partial x_{//}} + \frac{1}{\mu\sigma}\Delta b = 0.$$

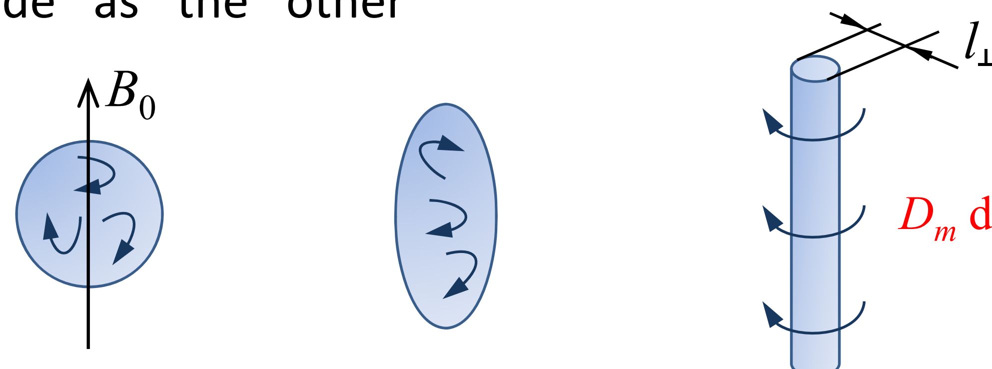
When B_0 becomes large enough, $\partial/\partial x_{//}$ becomes small in such a way that $B_0 \times \partial/\partial x_{//}$ remains of the same order of magnitude as the other terms

$$\frac{\mathrm{d}u}{\mathrm{d}t} = -\frac{1}{\rho}\nabla p + \nu\Delta u - \frac{\sigma B_0^2}{\rho}\Delta_\perp^{-1}\frac{\partial^2 u}{\partial x_{//}^2}$$

The Lorentz force appears as a diffusion in the direction of the magnetic field ($\pm B_0$), characterized by a magnetic diffusivity

$$D_m = \frac{\sigma B_0^2}{\rho}\Delta_\perp^{-1} \approx \frac{\sigma B_0^2 l_\perp^2}{\rho}$$

Initially isotropic structure



D_m does depend on $l_\perp$!

$t = 0$ $\qquad$ $t = \frac{\rho}{\sigma B_0^2} \approx 10^{-4}\,\mathrm{s}$ $\qquad$ $t = \frac{\rho}{\sigma B_0^2}\frac{l_{//}^2}{l_\perp^2} \approx 10^{-2}\,\mathrm{s}$

Current work

Current work: Mixed Convection Experiment

MHD Mixed Convection is probably one of the most complex MHD-related problems in Fusion Blankets.

Very rich dynamical problem, since several phenomena might occur at the same time:

- magnetic diffusion: tendency towards two-dimensionality
- transition from one flow pattern to another flow pattern through different types of instabilities
- transition from a laminar to a turbulent flow regime
- Vortex interaction
- Each of these phenomena has an impact on the temperature field and the way a passive scalar, like tritium, is transported!

The goal of the mixed convection experiment is to support/validate the theoretical and numerical predictions (which are based on the EDUCATED assumption that the flow is <u>fully developed</u> and <u>quasi-2-dimensional</u>).

Current work: Mixed Convection Experiment

The study has been divided into two parts:

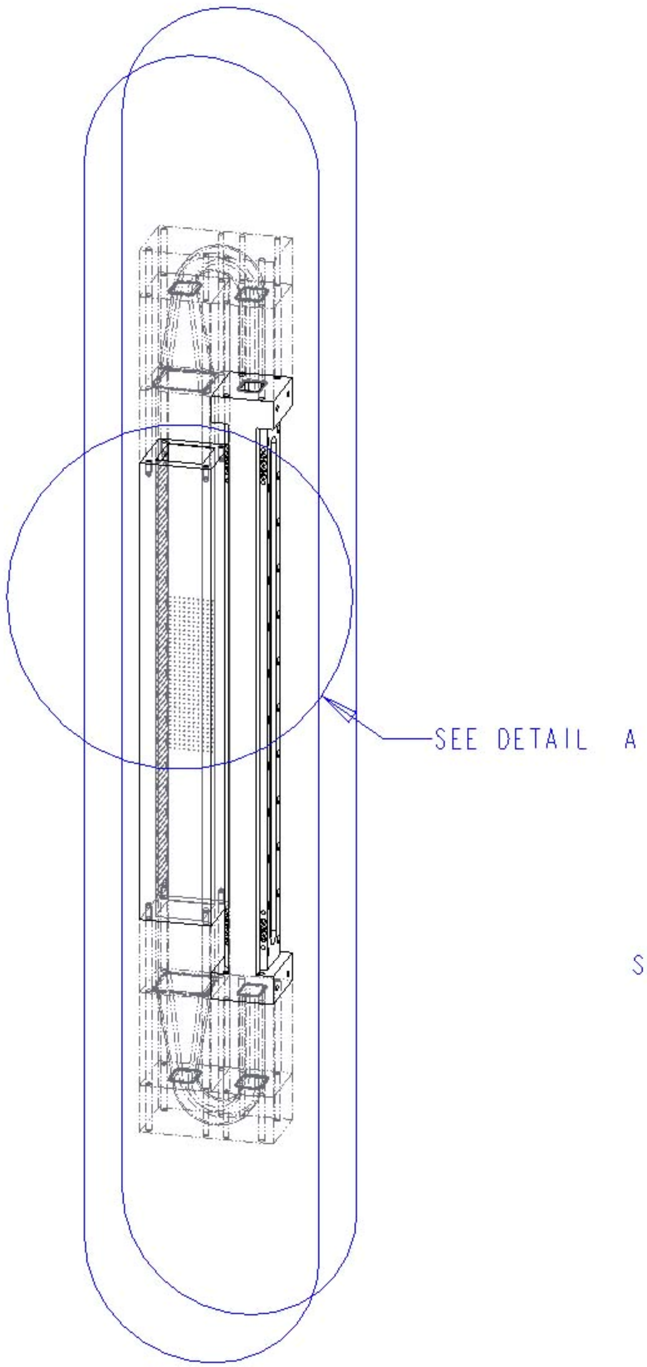
The first part aims at explicitly defining the validity limits of the quasi-2D theory through a relatively simple experiment (**Anisotropy Level Quantification Experiment**):

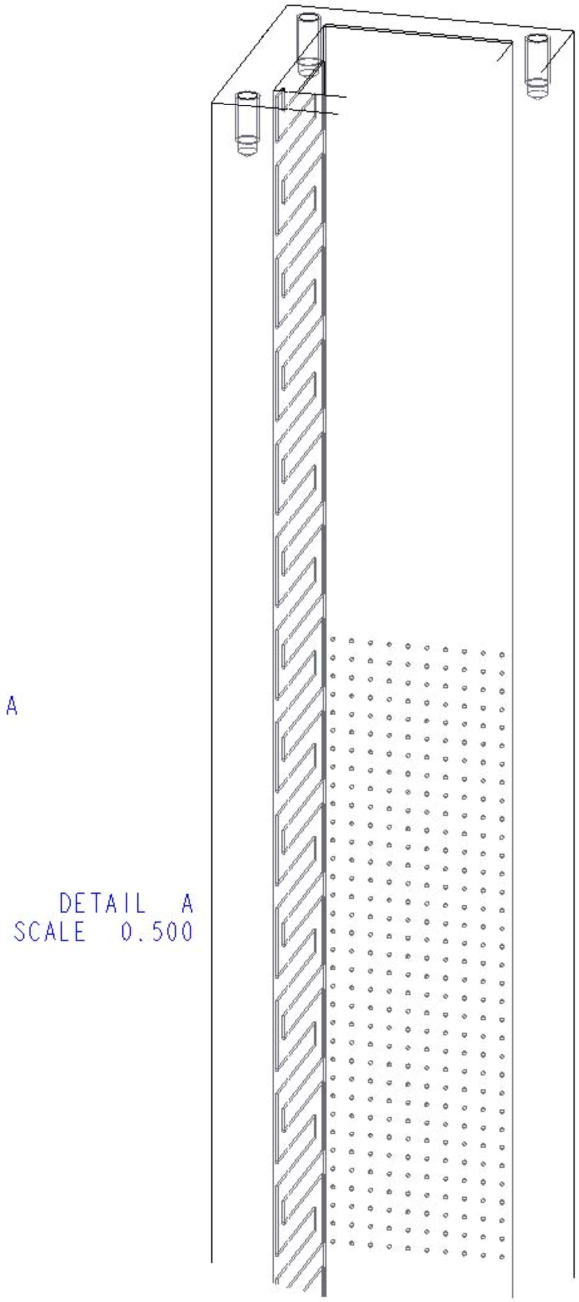
Values of Re and Ha for which a given flow structure defined by a its transverse scale $l_{\perp}$ is 2D (subsequently 3D)?

The second part of the study (**Mixed Convection Experiment**) aims at:

- Characterizing the different dynamical regimes of a buoyancy/pressure – driven flow submitted a steady transverse magnetic field
- Understanding the transport properties associated with each regime
- Validating the theoretical and numerical predictions

Mixed Convection Experiment





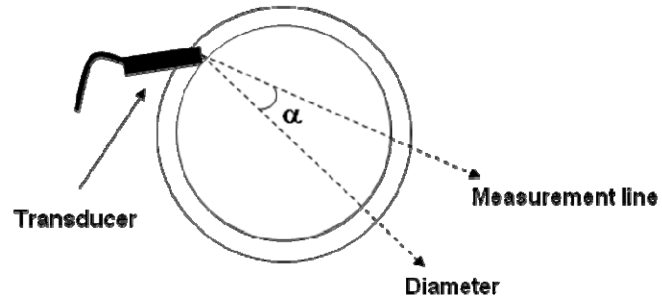
Diagnostics development

Ultrasound Doppler Velocimetry

Wall Inductive Velocimetry works only if the flow is quasi-2D (weakly 3D?).

In order to characterize purely 3D flow regimes (transitional flows that occur around geometrical/electrical/magnetic singularities), Ultrasound Doppler Velocimetry technique is used

We have performed an extensive study on a disk driven flow in a cylinder first with H2O and then with Hg using a commercially available UD Velocimeter

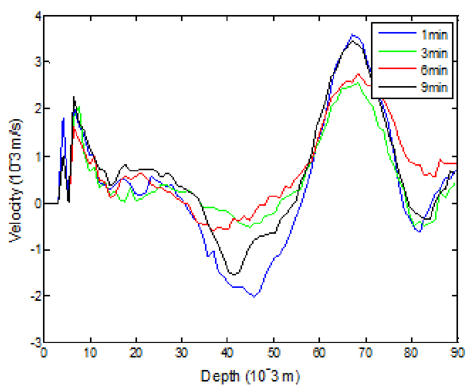


Ultrasound Doppler Velocimetry

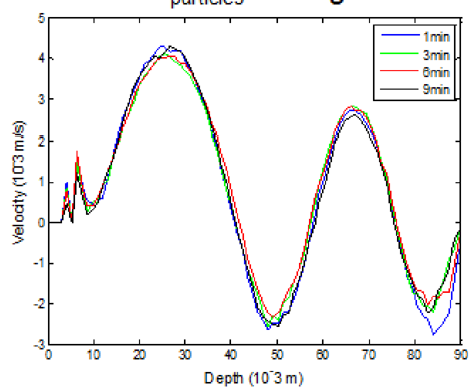
H_2O:

Strong dependence on tracers concentration

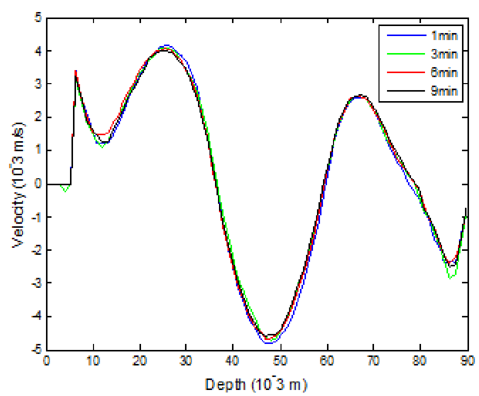
$C_{particles}$=0.17 g/L



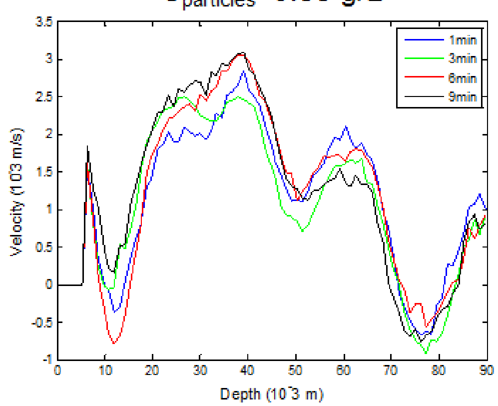
$C_{particles}$=0.25 g/L



$C_{particles}$=0.30 g/L



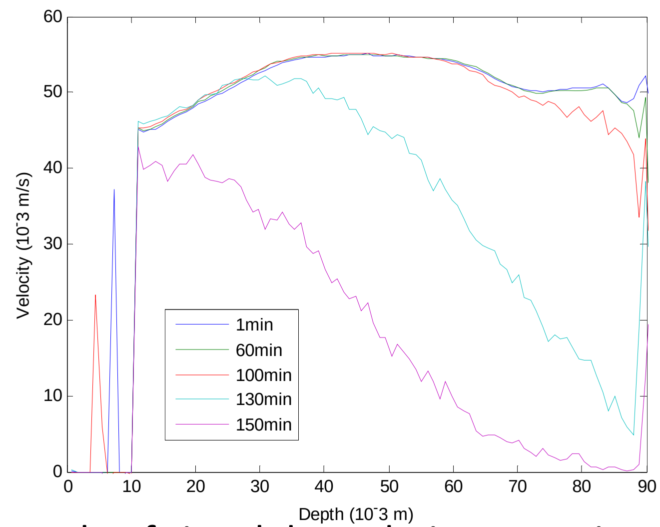
$C_{particles}$=0.35 g/L



Hg:

Not straightforward. Very limited choice of particles/tracers

Consistent signal degradation with time indicates that initial micro- bubbles generated during the filling act as tracer particles. After a certain amount of time these micro-bubbles coalesce and separate from the mercury under the combined effect of buoyancy and centrifugal forces.



Example of signal degradation over time(Hg)

Summary

Main Experiment	Supporting Experiments	Goals	Schedule
Mixed Convection Experiment		• Identify/Characterize the different dynamical regimes • Understand the transport properties associated with each regime • Model Validation	• Finalizing the design and fabrication will start in Oct 2009 • Wall potential probes design completed • BOB magnet Rotation (Jan 2010) • First experimental campaign should start in Feb 2010
	Multi-Scale Anisotropy Level Quantification	• Validity limits of 2D models • Error assessment on the inductive velocity measurements when the flow departs from two-dimensionality	• Assembly almost finished • Experiment should start in Sept 2009
	Diagnostic Development a] Disk-driven flow b] Pressure driven duct flow		Continuous effort