Lorentz force and power dissipation in turbulent flows

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Our Goals:

- experimental measure of local velocity in sodium flow driven by a known Lorentz force field \( F_L = J \times B \)

\[
\begin{align*}
\vec{J} & = \text{current density} \\
\vec{B} & = \text{magnetic field}
\end{align*}
\]

- use velocity measurements to yield local power input \( P = \vec{u} \cdot \vec{F} \)

\[
\begin{align*}
\vec{u} & = \text{local velocity of fluid element} \\
\vec{F} & = \text{local force on fluid element}
\end{align*}
\]
$\vec{F}$ (Experimental Cylinder):

- Produces turbulence in liquid sodium via Lorentz force
- Sodium allows for high Reynolds numbers, no significant heating
- $\text{Re} = D\nu\rho/\mu \sim 10^4$
\( u \) (Ultrasound Velocimetry):

- Transducer emits short US burst, then “listens” for echoes scattered off seed particles

- \( t = \frac{2x}{c} \), where \( t \) = time delay, \( x \) = distance of particle from transducer, \( c \) = speed of sound in medium
$u$ (Ultrasound Velocimetry):

- Received echo Doppler shifted
- $f_d = 2f_0(v/c)$, where $f_d$ = Doppler-shifted frequency, $v$ = velocity, $c$ = speed of sound, $f_0$ = transmitting frequency
- If $t, f_d$ measured can calculate position and velocity of particle
Results

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Results

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Results

**Graph 1:**
- **Title:** Applied Current 40 Amps, Applied Magnetic Field 360 Gauss
- **X-axis:** Depth (cm)
- **Y-axis:** Mean Velocity (with error) (cm/s)

**Graph 2:**
- **Title:** Applied Current 40 Amps, Applied Magnetic Field 360 Gauss
- **X-axis:** Depth (cm)
- **Y-axis:** Mean Velocity (with error) (cm/s)
Results

Time Trace for Depth=15cm, λ=40, β=360

Time Trace for Depth=25cm, λ=40, β=360

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Future Work:

- complete analysis of data
- comparisons of local power input with global power input measurements made in air and water flows
- comparisons with numerical data on power fluctuations in turbulent flows
- eventual cylindrical Couette liquid sodium experiment in presence of $\vec{B}$