Stabilization of the Resistive Wall Mode Using Moving Metal Walls

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Goal of rotating wall machine

A second conducting wall, rotating with respect to the first wall, can stabilize the RWM

Larger Br when $q_a < 1$ & suppression of Br with surrounding plasma.
RWM exists between ideal no-wall and with-wall conditions.

\[
\tau_c = \mu_0 \sigma_c \delta_c c \\
R_b = \omega_c \tau_c
\]

Diagram shows growth rate (Hz) against \(q_a\). The graph includesIdeal (x10^{-3})

- no-wall
- with-wall

Scale reduction in plotting ideal modes.
Seven gun plasma current exhibits sawtooth behavior

- sawtooth behavior found in plasma current
- plasma source able to supply plasma through disruption
- analysis underway
Longer MHD timescale associated with seven gun plasma
Flux loops on vessel surface monitor $B_r$

- two sheets each have 4X10 sets of 10 turn loops to act as pickups for flux
- eight loops along machine axis
- ten loops through poloidal plane.

\[ \nabla \times E = \dot{B} \]
Electrostatic plasma source provides control for density and current profiles

adjust current & density with gun array
Outline

- Motivation for moving walls
- Theory of the RWM in a line-tied pinch
- Description of apparatus
- Initial results of no wall limit
- Summary
The experiment: use current driven kink mode in a linear device as a RWM

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B_z$</td>
<td>0.2 T</td>
</tr>
<tr>
<td>$I_p$</td>
<td>20 kA</td>
</tr>
<tr>
<td>$\tau_{\text{pulse}}$</td>
<td>20 ms</td>
</tr>
<tr>
<td>$L$</td>
<td>1 m</td>
</tr>
<tr>
<td>$b, c$</td>
<td>0.10, 0.11 m</td>
</tr>
<tr>
<td>$\delta_{b,c}$</td>
<td>1-3 mm</td>
</tr>
<tr>
<td>$\tau_w$</td>
<td>8-24 ms</td>
</tr>
<tr>
<td>$f_{\text{shell}}$</td>
<td>$&lt; 100$ Hz</td>
</tr>
<tr>
<td>$Rm_b$</td>
<td>5-15</td>
</tr>
</tbody>
</table>

Conductive endplates in plasma column provide line tying boundary condition
Current free plasma improves stability

- One gun current carrying plasma
- Conducting end plates
- Pyrex wall
- Surrounding current-free plasma (6 guns)

Edge $q$ changes when plasma column diameter changes.
Different plasmas are represented in the data

- One gun carrying plasma current
  - Diameter ~3 cm
  - Pyrex wall

- Seven guns carrying plasma current
  - Diameter ~10 cm
  - Pyrex wall

- Seven guns, but only center one carries plasma current
  - Diameter ~10 cm
  - Pyrex wall
$m = 1$ growth rate determined at mode onset

Mode Evolution

- saturated signal
- linear growth

Linear Fit

growth rate is 11.15kHz
Slower MHD with seven guns reveals plasma rotation and m = 1, 2, 3, 4 structure.

One gun
Shot 40622044
Black; m = 1
Blue; m = 2
Red; m = 3
Green; m = 4

Seven guns
Shot 40929005
Black; m = 1
Blue; m = 2
Red; m = 3
Green; m = 4
Future directions

- complete parametric stability studies for no wall plasma with seven guns
- establish density and q profiles of plasma
- install thin wall and characterize RWM with one and seven gun plasmas
- install rotating wall on machine and characterize effect on RWM
$q_a < 1$ governs onset of MHD
Summary

- no-wall ideal instability grows when $q_a < 1$ (Kruskal Shafranov)
- increasing $q_a$ by enlarging plasma is stabilizing
  - see Mirnov JP1.057 aps
- $m=1$, $n = 1,2$ modes dominant
- seven gun plasma has growth rate of 11 kHz
Instability shows coupled $n = 1$ and $n = 2$ character and rotation.
MHD Stability of the Line-tied Screw Pinch

- the no-wall instability limit set by \( q_a = 1 \) (Kruskal Shafranov)
  - \( q_a < 1 \)
  - \( q_a = \frac{4\pi^2 a^2 B_z}{\mu_0 I_p L} \)

- with wall instability limit
  - depends upon proximity of shell
  - \( q_a - 1 + \left(\frac{a}{b}\right)^2 < 0 \)
  - Resistive Wall Mode exists between with wall and no-wall ideal limit
  - two shells, one spinning
  - recent theory