High beta simulations of MST

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Finite pressure effects in the RFP

**Experiment:**
- The Mercier criterion parameter exceeds the stability threshold. No severe effect was observed in experiment. [M. Wyman et al. Phys. Plasmas 2008]
- Preliminary measurements show slightly higher low-n fluctuation level at high density (high pressure). New high beta experiments are underway.

**Simulations:**
- MHD simulations show that both localized and global pressure-driven modes remain resistive at betas several times the Suydam limit [Ebrahimi, Prager, Sovinec PoP 2002]
- Resistive interchange modes are unstable in torus and have growth rates close to cylindrical growth rates.
- FLR effects suppress the growth rates of interchange modes, however they are not completely stabilized.
NIMEQ solver is modified to read MSTFIT profiles.

Finite Element Mesh

NIMEQ [Howell and Sovinec]

$$\Delta^* \psi = -F(\psi) F'(\psi) - \mu_0 R^2 P'(\psi)$$

- $F(\psi) = R B_{tor}$ and $P(\psi)$ are polynomial functions. Coefficients are obtained using least square fit to the data.
MSTFIT profiles (High beta - Mercier criterion exceeds the ideal stability limit)

\[
\lambda
\]

\[
q
\]

\[
F = R B_{tor}
\]

\[
\mu_0 P
\]
NIMEQ profiles

mu vs. pol_flux

mu vs sq(pol_flux)

q vs. pol_flux

q vs sq(pol_flux)

High beta simulations of MST
Resistive pressure-driven modes are unstable.

**Linear growth rates**

\[ \tau_A = 6 \times 10^{-7} \text{ sec}, \ S = 5 \times 10^5, \ n = 2.7 \times 10^{19} m^{-3}. \]

- Global pressure-driven m=1 modes have tearing parity.
- Pressure-driven \( m > 1 \) modes have interchange parity.
- MHD toroidal growth rates are close to the cylindrical ones.
- Modes with max growth rates are resonant around \( r/a=0.32 \) (q=1/7)
The growth rates of interchange modes are reduced by 2-fluid and gyroviscosity.

Ideal stability for $\omega^* > 2\gamma_{\text{mhd}}$ or $k\rho_i > \frac{2\gamma_{\text{mhd}}L_p}{v_T}$

where $\omega^* = k\rho_i v_T / L_p \sim 5 \times 10^4$

2-fluid $E + V \times B = \eta J + 1/neJ \times B - 1/en\nabla P_e + m_e/e^2 n\partial J/\partial t$

gyroviscosity $\rho(\frac{\partial V}{\partial t} + V \cdot \nabla V) = J \times B - \nabla P - \nabla \Pi$
2-fluid mode structure has signature of diamagnetic rotation

n=6

n=13

n=21

n=28

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High beta simulations of MST
MSTFIT profiles (low beta - ideally stable)

MSTFIT profiles

NIMEQ profiles

mu vs. pol_flux

q vs. pol_flux

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High beta simulations of MST
Resistive modes are unstable (plasma is ideally stable).

Linear growth rates

\[ \tau_A = 6.6 \times 10^{-7} \text{ sec}, \ S = 8 \times 10^5, \ n = 3 \times 10^{19} \text{ m}^{-3}. \]

- All n’s are unstable, growth rates are small (\( \gamma \tau_A \approx 1.e - 3 \))
- For a particular n, azimuthal mode numbers \( m=1,2, 3 \) could be unstable
Mode structure for $n=21$ which is resonant at three different radii with azimuthal mode numbers $m=1, 2, 3$.
Resistive interchange modes are unstable in torus and have growth rates close to cylindrical growth rates.

FLR effects suppress the growth rates of interchange modes, however they are not completely stabilized for high beta plasma in MST.

Gyroviscosity also has strong stabilizing effect on the resistive modes at lower beta plasmas in MST.