MagLIF is a fusion concept that involves imploding an initially solid cylindrical metal liner (Aluminum or Beryllium) on to a pre-magnetized Deuterium-Tritium (D-T) fuel target [Slatz et al., 2010]. The most detrimental instability toward achieving net gain is the magneto Rayleigh-Taylor instability (MRT) that occurs at the accelerating liner-vacuum interface during implosion. As the current from the pulse ionizes the solid liner the resulting process produces an exterior coronal region where the configuration is MRT unstable. Sinars et al. [2011] recently performed MRT experiments with the intent of providing a benchmark for new models. Peterson et al. [2012] suggests that the electro thermal instability (ETI) seeds the MRT instability early in the simulation. This project seeks to find more insight in the transition of the ETI to the MRT through the use of kinetic closures developed for moderately to weakly coupled plasmas.

**Simulation Setup**

The USim code from Tech-X Corp. is used to simulate the MRT instability using the magnetohydrodynamic (MHD) model with the SESAME equation of state (EOS) tables from Los Alamos National Laboratory. USIM [2017] Simulations of linear waves, Brio-Wu shock propagation, and Rayleigh-Taylor were performed to verify the implementation of the SESAME EOS tables using test cases from the Achena code. Stone et al. [2008] These tests revealed that the sound speed needed to be reconstructed on cell interfaces instead of cell centers to obtain meaningful results using the SESAME EOS tables with the finite volume algorithm. Figure 1 presents the typical setup and parameters of the simulation to study the MRT instability.

The figure shows parameters in cylindrical coordinates, but all simulations run thus far have been using Cartesian coordinates. From the diagram \( B_0 \) at the outer liner radius is given by

\[
B_0(r) = \frac{\mu_0 I(t)}{2\pi r(t)} \tag{1}
\]

where \( I \) is the liner current assumed to be concentrated at the surface, \( r_0 \) is the outer radius of the liner, and \( \mu_0 \) is the vacuum permeability. The magnetic pressure applied to the outer liner surface \( \rho \) is given by

\[
\rho = \frac{B^2}{\mu_0} \tag{2}
\]

The force is obtained using \( P_0 \) and the surface area, which is used to obtain the acceleration. After applying some elementary approximations and simplifications, the acceleration is given by

\[
a(t) = \frac{\mu_0 I(t)}{4\pi m(t)} \tag{3}
\]

where \( m = 2\pi r_0 \Delta n_0 \), with \( \Delta n_0 \) representing the initial liner outer radius, initial liner thickness, and initial liner density, respectively. \( I(t) \) and \( n(t) \), which are determined from Slatz et al. [2010], are given by

\[
n(t) = n_0 \left(1 - \exp^{-t_0} \right) \tag{4}
\]

and

\[
I(t) = I_0 \left(1 + \exp^{-t_0} \right) \tag{5}
\]

where \( t = t_0 \times n_0 \) with \( t_0 \) representing the time of the current pulse (132 ns), and \( I_0 \) is the peak current = 20 MA. Thus Eqs. (3) (5) complete the analytical form for the time varying gravitational acceleration for MagLIF-relevant conditions. All simulations conducted used MHD with either ideal-gas EOS, or SESAME EOS.

Figure 2: Cross-sectional end view of MagLIF where \( I \) is the linear current in the \( z \)-direction, \( n_0 \) is the initial liner outer radius. \( \Delta n_0 \) is the initial liner thickness. \( B_0 \) is the azimuthal field created by \( I \), and \( P_0 \). \( A_l \) is the pressure force acting radially inward.

The functional form of the multimode perturbation used is

\[
\delta V_\lambda = \frac{\lambda_\lambda}{2\pi} \cos(2\pi \frac{x}{\lambda_\lambda} + \beta_\lambda \tau) \tag{6}
\]

where \( \beta_\lambda \) is a random number from 0 to 1, \( \lambda_\lambda = 200 \) \( \mu m \) is the maximum wavelength associated with the lowest mode. The multimode simulation incorporates the seeded magnetic field. The seeded magnetic field will vary during the implosion through flux compression. To accurately depict this, a piece-wise magnetic field \( B_0 \) is used to vary the magnetic field source term (multi-mode only). The multimode has shown agreement to the effect of the axial magnetic field on damping the smaller wavelength modes.

Figure 3: 7th experimental plot from figure 12 of [Sinars et al., 2011]

Summary

A 2D planar simulation of MRT instability with different EOS is conducted using a time varying gravitational source term, and a time varying magnetic field source term (multi-mode only). The single mode simulation has shown promising agreement with the growth shown in the Sinars et al. [2011] paper. The multimode has shown agreement to the effect of the axial magnetic field on damping the smaller wavelength modes.

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Table 3720 for Alumni is used in all the simulations shown, as this incorporates the most relevant recent physics for EOS tables by using the GRIFFIN Lani code with additional modifications.Crockett [Aug. 30] In addition work has been done to validate this table for use in other HEDP codes such as Alagha.Kochane et al. [2006]

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