Plans for Modeling Plasmas in the Presence of Conducting Liquid Walls

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Outline

- Plans for Supporting Tasks I, II, and V
- Description of Tokamak Simulation Code
- TSC Simulations of NSTX Discharge
- TSC Simulation of BP-ST Discharge
- Issues for TSC Liquid Wall Simulations
- Summary

Task I. Explore options and issues for implementing a flowing liquid wall in a major experimental physics device

- I.1 Characterization of NSTX plasmas:
  - Supports ALIST effort that also includes interest in Alcator C-MOD plasmas

- I.5 Identification of key issues and development of an R&D plan for implementing liquid walls in NSTX:
  - Includes identifying results and proposing experiments with CDX-U lithium limiter plasmas that could affect NSTX proposals

- I.4 LM experimental facility set up and initial exploratory experiments with and without a magnetic field gradients and applied currents:
  - Supports MTOR experiments and upgrades

Task II. Exploration of High-Payoff Liquid Wall Concepts

- Engineering properties of the liquid lithium itself:
  - Further comparisons between methods of propulsion and tests on experimental devices (talk by L. Zakharov to follow this presentation)

Task V. Plasma Stabilization

- Stabilizing effects of liquid lithium on MHD modes:
  - Efforts at IFS and PPPL will continue to evaluate conditions under which liquid lithium walls will affect resistive wall mode

- Transport and profile effects of low-recycling properties of lithium:
  - Provide information from simulations of CDX-U liquid lithium experiments and other computational efforts to help develop a model for a spherical torus plasma in contact with a very low recycling surface
  - Effort includes modifying Tokamak Simulation Code (TSC) to simulate liquid walls if feasible

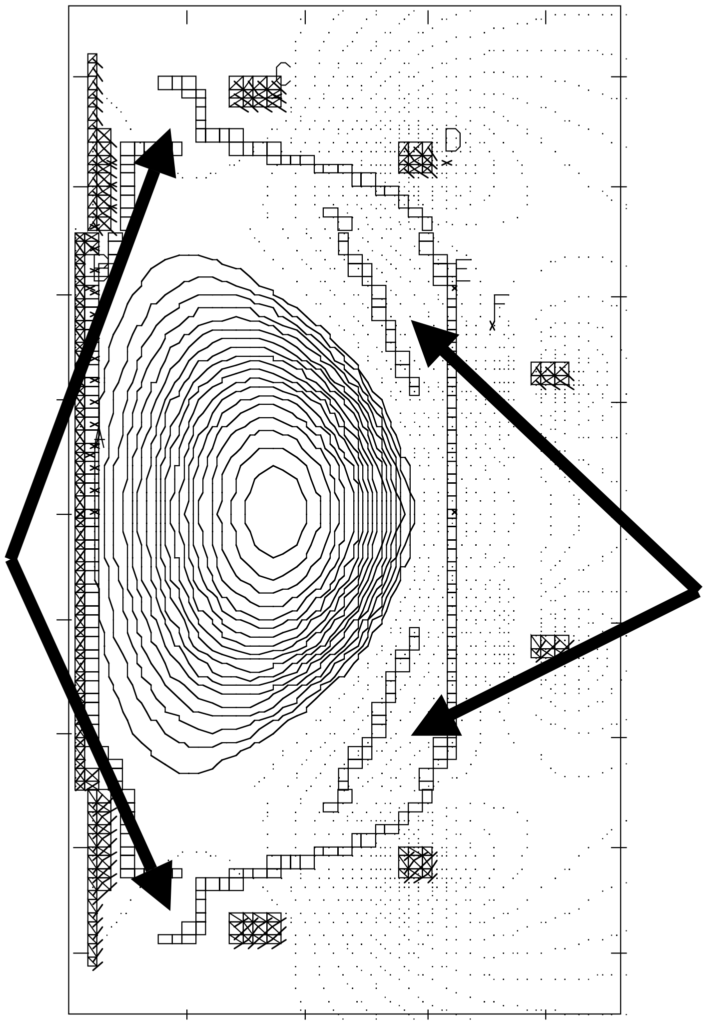
Description of Tokamak Simulation Code (TSC)

- 2-D, time-dependent, free-boundary simulation code -
  - advances MHD equations for evolution of axisymmetric magentized toroidal plasma on transport time scale
  - evolves magnetic field in a rectangular computational domain
  - Maxwell MHD equations for plasma
  - couples via boundary conditions to circuit equations for poloidal field coils

Description of TSC (continued)

- Plasma model uses functional forms for:
  - electron and ion thermal conductivities
  - particle diffusion coefficients
  - plasma electrical resistivity
- Transport model is semi-empirical:
  - adjustable parameters to fit experimental database
- Reference: S. C. Jardin, N. Pomphrey, and J. L. DeLucia, J. Comput. Phys. 66, 481 (1986).

TSC Simulation of 1 MA NSTX Discharge

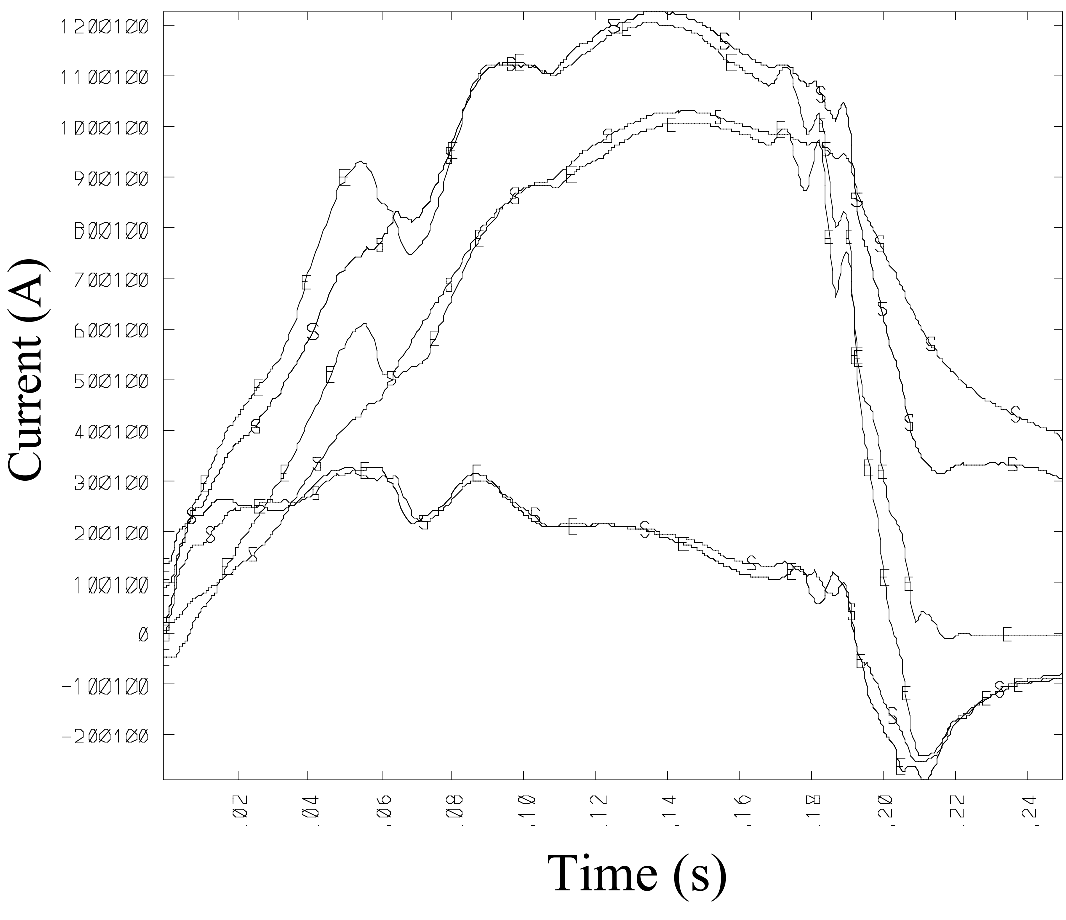


DC breaks in vacuum vessel for coaxial helicity injection

Passive stabilizer shell

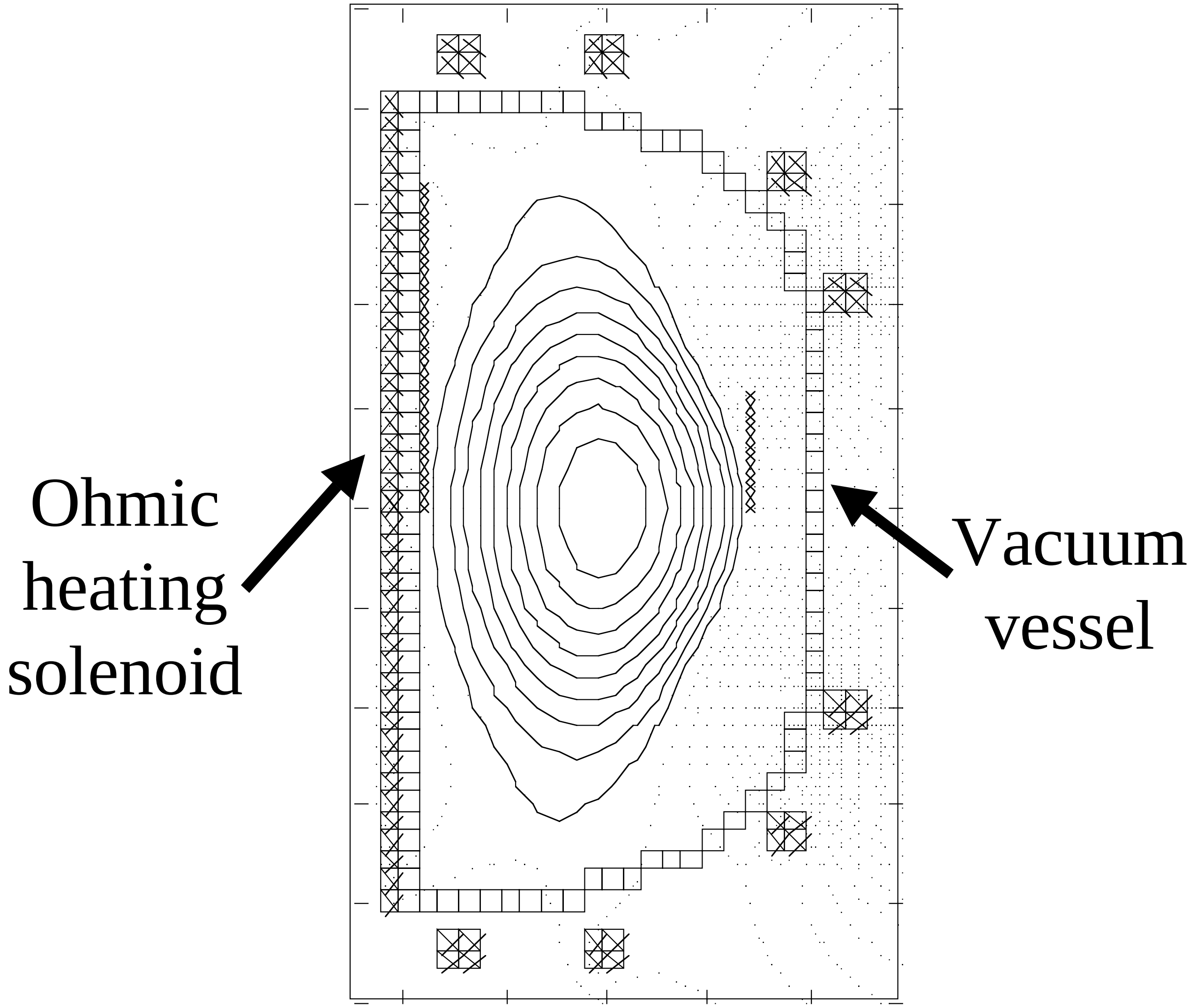
Poloidal flux near peak of plasma current

TSC Simulation of 1 MA NSTX Discharge (continued)



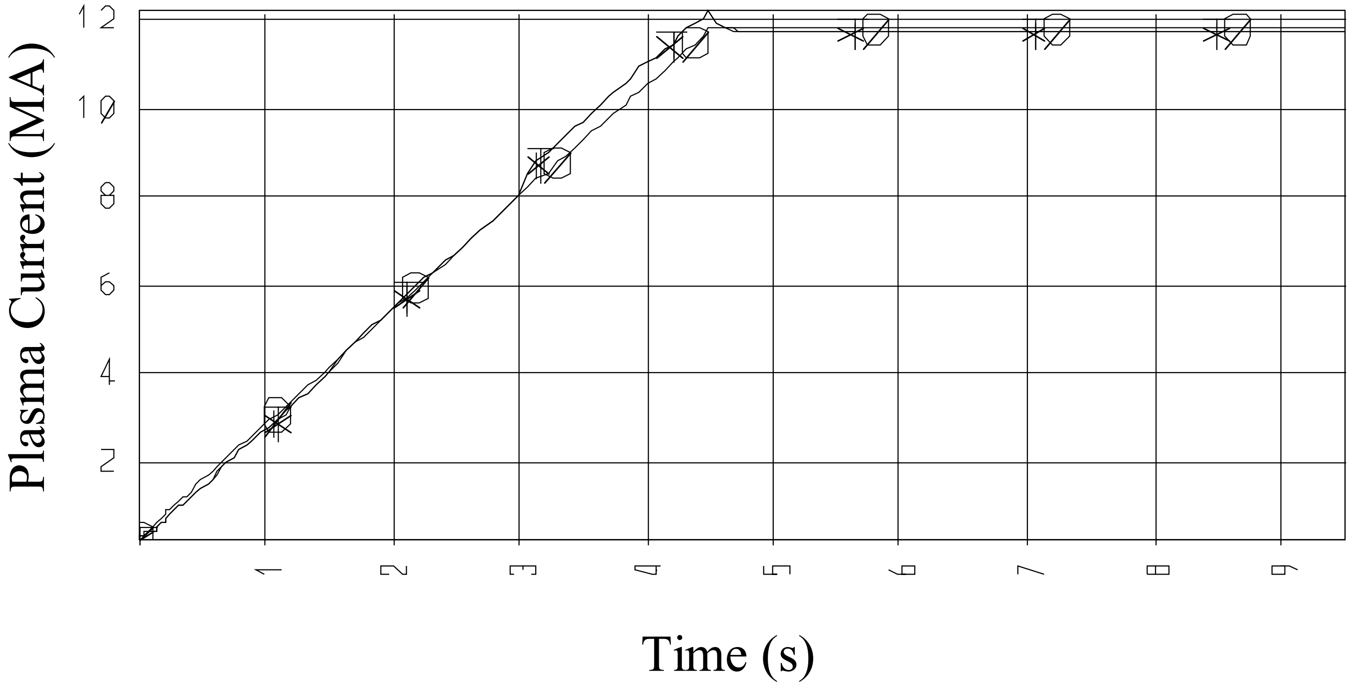
Comparison of TSC results (S) with experiment (E) for NSTX plasma + vacuum vessel current (upper), vacuum vessel current (lower), & plasma current (middle).

TSC Simulation of 12 MA Burning Plasma ST (BP-ST) Discharge



Poloidal flux at peak of plasma current

TSC Simulation of 12 MA BP-ST Discharge (continued)



Time evolution of plasma current in BP-ST spherical torus discharge simulation with TSC

Issues for Simulation of Interactions Between Plasmas and Liquid Walls

- Effects of fully non-recycling lithium target on plasma
  - Plasma current penetration and equilibrium control
  - Deuterium fueling and lithium impurity accumulation
  - Effects on plasma confinement and RF coupling/heating

  Simulating effects by varying particle confinement time planned

- Effects of plasma on the liquid lithium surface
  - *jxB* forces on lithium during MHD activity and disruptions
  - Possible surface coatings such as lithium hydride

Estimating *jxB* Effects of Plasma on Liquid Lithium Wall

- Current densities induced at location of possible lithium surface can be calculated with TSC
  - Conductivity of lithium is similar to that of stainless steel vacuum vessel typically assumed in TSC simulations

- Current densities estimated for NSTX and BP-ST cases
  - $J = 4 \times 10^5$ A/m^2 for NSTX case
  - $J = 3 \times 10^4$ A/m^2 for BP-ST case (slower current ramp rate to higher final value)

- Need to determine how these current densities translate into requirements for flow rates required for viscous force to counteract MHD by performing free surface fluid calculations.

Requirements for Free Liquid Lithium Surface Simulations in TSC

- TSC has to be modified to model free liquid lithium surface at plasma boundary
  - TSC presently performs fluid MHD calculations for region between plasma and wall
  - Density and temperature for this region specified as input
  - Parameters at plasma edge then varied to match these parameters so “discontinuous” boundaries presently not possible.

Summary

- Task I and Task II activities include involvement in experiments and upgrades on CDX-U and MTOR as well as supporting ALIST interest in NSTX

- Task V effort includes continuing work on MHD stabilization with liquid metal walls and investigating utility of TSC for plasma simulations with liquid walls
  - Spherical torus plasmas have been modeled with TSC
  - Estimates obtained of current densities induced at location of liquid metal wall
  - TSC needs modification to simulate free surface for liquid lithium at plasma boundary