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Numerical Studies and Metric Development for Validation of MHD Models on the HIT-SI Experiment[1]

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Biorthogonal Decomposition (BD) decomposes large data sets, as produced by distributed diagnostic arrays, into principal mode structures without assumptions on spatial or temporal structure. We present an application of the BD technique to define a few scalar metrics that capture the level of agreement between macroscopic dynamics in different data sets. These metrics have been applied to validation of the Hall-MHD model using experimental data from the Helicity Injected Torus with Steady Inductive helicity injection (HIT-SI) experiment. Each metric provides a measure of correlation between mode shapes extracted from experimental data and simulations for an array of 192 surface mounted magnetic probes. In collaboration with the Plasma Science and Innovation (PSI) Center, extensive simulations have been performed and compared to experimental data using BD and other metrics to determine validity of the Hall-MHD model in the parameter regime of HIT-SI operation (T $\sim$ 10's eV, n $\sim 10^{19}$ m^{-3}). Numerical validation studies have been performed using NIMROD [1], which models the injectors as boundary conditions on the flux conserver, and PSI-TET [2], which models the entire plasma volume. Results from these studies will be presented, illustrating application of the BD method. A simplified (constant, uniform density and temperature) Hall-MHD model has accurately modeled the current amplification achieved when the injectors are driven with a frequency of 14.5 kHz. However at higher frequencies (30 kHz $< f_{inj} <$ 70 kHz) this simplified model does not reproduce the experimental current amplification. In addition, simulations have yet to accurately reproduce the internal q profile, an important factor in equilibrium stability, indicating additional physics may be required to achieve full agreement.

[1] C. Akcay, Physics of Plasmas (2013).
[2] C. Hansen, PhD Dissertation: University of Washington (2014).

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