NIMROD Team Meeting Minutes
March 14, 2015, New York University, New York

Computational topics:

Carl Sovinec presented development needed for simulating 2D and 3D vertical displacement events in tokamaks. NIMEQ has been modified to find equilibria with a separatrix and distinct closed/open-flux profiles for diverted tokamaks in cases where an externally generated equilibrium is not available. The algorithm traces $\mathbf{B}_{pol}$ during the Grad-Shafranov iterations to a fixed distance, and field-lines that reach a prescribed length without hitting the wall are treated as closed. A new grid-block-based search and reuse of information make the computations tractable. The algorithm can be used to refit externally generated equilibria, but King's FGNIMEQ method is expected to be more accurate and faster. Dylan Brennan suggested that the "in polygon" method would be faster if one can identify the separatrix surface. Sovinec also described parallel coding development for running with multiple regions (plasma and external vacuum) but noted that it did not reproduce all 1-processor results by the time of Sherwood.

Scott Kruger presented Jake King's recent work for modeling edge harmonic oscillation (EHO). Obtaining sufficient resolution for this application is proving to be more challenging than any other study, due to the edge current density profile with large rotational shear. The usual trick of smoothing the edge pressure profile makes the maximum $dP/d\psi$ larger, unphysically enhancing ballooning. Data from DIII-D shows that the scrape-off layer supports current, which is not included in EFIT. King extrapolates splines of P and F over the separatrix to make the scrape-off current-density profiles smooth and roughly fit the experimental data. The maximum scrape-off layer current density at the footpoint is about 10 kA/m^2, which is less than the ion saturation current density. He also incorporates **E**x**B**, diamagnetic, and parallel flows from experimental information. His computations based on the new equilibrium fields use all two-fluid terms for a consistent gyroradius ordering. Linear convergence studies are underway.

Simon Woodruff, Danielle Lemmon, and James Stuber are developing a set of synthetic diagnostics for model validation studies; John O'Bryan presented the work for them. The software is being developed in the Octave mathematical software to avoid the expense of Matlab while being able to take advantage of dump-file conversion utility written by Richard Milroy for Matlab. A suite of diagnostics is planned. The first to be developed are arrays of magnetic coils, density measured along arbitrary chords in the R-ϕ plane for synthetic interferometry, and B measured along arbitrary chords for synthetic polarimetry. Array data can be shown as movies over time. Reading experimental data and plots making direct comparisons are planned.

Physical model development:

Josh Sauppe described his recent analysis that provides detailed accounting of momentum, energy and helicity in two-fluid modeling. He noted that the NIMROD equations do not enforce momentum conservation due to the artificial particle diffusivity and the equilibrium pinch flow. Net momentum also changes due to viscous coupling with the wall. Sauppe has separated each term in the momentum-density evolution. In his S=20,000 Pm=1 RFP computations, net change in momentum is much larger with two-fluid modeling than with MHD. The contributions from viscous stress at the wall are much larger than artificial diffusivity and pinch terms, but warm-ion cases have appreciable cancellation between gyroviscous stress and isotropic stress. Sauppe reviewed two-fluid helicity theory; contributions can be categorized as magnetic, cross, and kinetic, although existing theories do not consider warm ions. His MHD, two-fluid/cold-ion, and

two-fluid/warm-ion cases all show magnetic helicity to be better conserved than energy during relaxation events. Resistive diffusion dominates magnetic energy change during crashes. The electron pressure contribution is dropped in theory (assuming barotropic responses) and proves to be small in simulation. The cross helicity is affected by viscous stress during simulated events, especially with warm ions. A discrepancy with respect to thermal energy evolution is under investigation.

Eric Held gave an update on all closure research at USU that is related to NIMROD modeling. He first reviewed the drift-kinetic model. His implementation in NIMROD now uses spectral elements in pitch-angle where element boundaries may be varied over the flux-function coordinate to better match trapped-passing boundaries over the entire cross section. Numerical convergence results for the hot-particle kink benchmark show the benefits well-chosen pitch-angle meshing. He uses an equilibrium distribution specification that is consistent with Fu's PoP 13 paper. Held is also applying his DK-MHD modeling to the reversed-shear Aflven eigenmode computations posed in Spong's PoP 19 paper. Jeong-Young Ji has continued his analytical work and has succeeded in unifying closure results over the last 20 years for the entire range of collisionality. His paper that presents fitted kernel functions for integral closures has been accepted, and a paper on heat flow in stochastic field has been submitted.

Chang Liu presented his work on modeling runaway electron effects on nonlinear MHD evolution. He is using and modifying NIMROD's PIC energetic particle capability for self-consistent kinetic modeling. He reviewed the current-based coupling scheme and modifications for full-f RE modeling. Future plans include a relativistic collision operator. He presented results on magnetic island evolution (tearing) in slab geometry, where the simulated orbits follow the full magnetic field. Liu is also considering the problem of runaway electron generation and the discrepancy between observed runaways and the critical field predicted by Connor and Hastie.

Applications:

John O'Bryan is revising spheromak modeling in preparation for a new experiment that is being considered by DARPA and would be managed by UMBC. He has updated previous SSPX modeling using improvements to the numerical methods and including his thermal conduction model with magnetization effects. However, the goal is to investigate improved configurations and not just extend previous SSPX simulation studies. The new simulations reproduce the column mode that is critical for formation, and a large amount of flux amplification is generated. 3D movies of ion temperature help illustrate how the toroidal asymmetry varies over formation and into the post-formation phase.

Fatima Ebrahimi presented her investigation of MHD reconnection and plasmoid formation for coaxial helicity injection in NSTX. She considers plasmoid instability to be the main mechanism for fast flux closure in the experiment, and it is related to helmet streamer development in the solar corona. She has explored parameters such as magnetic diffusivity, injector voltage, and the geometry of the gap and poloidal-flux footpoints to establish the requirements for the formation of closed flux. With a highly refined mesh, large S-value, and the narrower NSTX-U footpoints, she finds full closure of the poloidal flux and all current transitioning to the closed-flux region.

Jonathan Hebert gave an update on his modeling of CTH, in particular trying to understand the current hesitations observed during ramp-up. Lowering perpendicular thermal conductivity leads to earlier island formation in the simulations, when the experiment shows the hesitation, but the

simulated current ramp is not affected. Hebert is considering other possible effects such as two-fluid physics and limiter physics.

Nick Roberds presented his investigations of a variety of MHD behavior. He first described sawtooth computations that are based on cylindrical studies from the 80s. He uses Mathematica to identify equilibria of interest, loads the resulting profile information into VMEC to generate corresponding toroidal equilibria, then uses processes the VMEC equilibria for running NIMROD. His disruption computations are based on work by Carreras, where the disruptive nonlinear behavior results from island overlap. Roberds is also investigating resolution requirements for tearing modes in the presence of imposed helical fields. Time-step convergence is slowed by the presence of the external fields. Sovinec suggested that the 3D semi-implicit operator (needs to be resurrected) may improve convergence.

Tom Jenkins reviewed the giant sawtooth study, starting with motivations and experimental results. He noted that there had been a conflict between FLUXGRID assuming positive poloidal flux and the actual values from EFIT. King corrected this recently. It changes the sign of some of the drift orbits, and the particle loading needs to be updated for this correction. Recent results are computed with the separatrix and open-field region. They show the stabilization effect on the internal kink, but the fishbone destabilization does not appear, in contrast to previous results. Jenkins also compared Held's continuum-based approach and its new capability of including the RF tail in the distribution function.

Michael Halfmoon presented his work on energetic particle effects on tearing modes. He is using a step-function equilibrium for analytics in order to use an approach that is similar to Hu and Betti, except that Halfmoon is applying the analysis to 2/1 tearing instead of RWM. Numerically, he is using a shaped profile with NIMROD energetic particle module. Scanning the hot-particle fraction, he shows that the threshold for linear tearing is sensitive to the hot-particle population.