NIMROD Team Meeting Minutes
October 25, 2014, New Orleans, Louisiana

The format of this meeting aimed for shorter and fewer talks to allow more time for discussion.

Computational topics:

Carl Sovinec started the computational part of the meeting by describing the utility of an implicit hyper-dissipation operator (four curls) in the implicit Hall advance as a means to make the operator mathematically coercive. The formulation includes a hyper-divergence-cleaning (two grad-divs) operator. The implementation with NIMROD's C^0 expansion uses an auxiliary vector. First results include a nonlinear two-fluid RFP computation to show that a relatively low-resolution case runs robustly. The machinery will allow implementation of other 4th-order differential operators.

Jake King described the coupling of Fluxgrid and NIMEQ to provide a means to re-solve equilibria with a separatrix and to realign meshes with refined equilibrium fields. The new FGNIMEQ code calls Fluxgrid to interface with equilibrium reconstruction files, generate an initial mesh and map the initial fields. FGNIMEQ can then iterate between NIMEQ, which solves the Grad-Shafranov equation, and Fluxgrid, which generates a new flux-aligned mesh with the NIMEQ solution. The mesh realignment step is optional, and several cases have been improved just by re-solving the equilibrium with NIMROD's bases. The important distinction with the previously existing NIMEQ re-solve is that FGNIMEQ routines compute the location of the separatrix and uses it to distinguish the closed-flux region from the private-flux region to enable solutions with diverted flux. The code is functioning and has parallel capabilities necessary for high-resolution cases. Eric Held has used it for his TAE computations, Andi Becerra has used it for her NSTX case and Jake has used it for DIII-D EHO cases.

Physical model development:

John O'Bryan presented his development work in two different areas. The first is his development of magnetization effects for fluid ion gyroviscosity. He separates the fluid stress tensor into three parts, and ion magnetization $\left(\Omega_i \tau_i\right)$ appears in coefficients of the different parts. The high-magnetization limit matches the previous stress-tensor implementation, and the low-magnetization limit is isotropic. Full nonlinear computations allow spatial variation and temporal evolution of magnetization. Jeong-Young Ji's K2 model is an option within the same implementation. O'Bryan's second development topic is an investigation of solving an equation for ln(n) instead of the usual continuity equation to avoid negative values of n in computations of external-mode evolution. This approach is more common in space physics, where plasma density varies by orders of magnitude. At this point, computations with ln(n) run but become noisy, and O'Bryan is investigating ways to avoid noise.

Andi Becerra reported on new results with the Green's function resistive-wall implementation. She summarized the different interpolation schemes that Jake King investigated for the coupling between NIMROD and GRIN, which have different basis functions. The best approach requires interpolation of the GRIN magnetic potential over multiple points. Becerra now has results for an NSTX case, were the equilibrium is refined with FGNIMEQ. The edge resistivity is relatively large, but S in the open-field region is ~1000. Linear NIMROD computations find a mode in the conducting-wall limit, but the growth rate varies as the wall resistivity is increased from 0. It may be a resistive-plasma mode. Larger-n modes are also unstable.

Kyle Bunkers described his upgrades to the Stitch program that is used to assemble different sets of grid-blocks. The modifications allow assembly of a topologically annular region from topologically spherical regions. The development is needed for modeling external vacuum regions when using gridded vacuum computations. Another new feature is that Stitch can read dump files in a reset type operation, but it also reads equilibrium fields to retain NIMEQ Grad-Shafranov solutions computed in the pre-assembled blocks.

Applications:

Tom Jenkins is revisiting Dalton's linear computations for the giant sawtooth application. One finding is that upgrades to Fluxgrid lead to quantitative changes to growth-rates, but Jenkins finds that he can get very close to the original results by increasing the upper limit on poloidal flux used by Fluxgrid. With this, he is able to get linear computations with PIC fast-particle modeling to agree well with Dalton's results. Other findings are that the documentation of the critical energy input parameter is incorrect and that the ψ_0 -parameterization is not general. Initial efforts with nonlinear cases encounter numerical instability near the magnetic axis, and linear 2-fluid cases are problematic. The team discussed the possibility of making the explicit weight-equation contributions in the PIC and continuum models to have the same physical contributions. Those interested in the GS modeling will start holding regular calls.

Bick Hooper presented his recent efforts to understand the extent of magnetic flux closure observed in transient coaxial helicity injection (TCHI) in NSTX. He has been investigating the effects of density injection and radiation that is based on a model for oxygen. Low density in these computations helps indicate regions outside the plasma, and Hooper uses extra radiation there to avoid unphysical heating. Radiation is also enhanced near the injection, which is experimentally plausible given the plasma-surface interactions there. Through local cooling, hence locally larger resistivity, the enhanced injector-region radiation leads to greater flux closure in comparison with simulations that do not have this enhancement.

Fatima Ebrahimi presented her recent work on two topics. The first is modeling for NSTX/NTSX-U. Her previous computations started with 0-β modeling in 2D, and she is progressing to two-fluid physics (another possible mechanism for more flux closure), 3D effects, and time-dependent boundary fields. Fundamental reconnection physics during NSTX CHI discharges, including plasmoid instability was shown. Her new NSTX-U simulations also show a maximum volume of flux closure. The second topic is modeling laboratory experiments that investigate the magneto-rotational instability. The computations start with purely toroidal field and a Keplerian flow profile. Ebrahimi's NIMROD results show qualitatively different behavior when running resistive MHD and two-fluid models. MHD only produces small-scale magnetic fluctuations, but the Hall effect leads to an inverse cascade and the generation of large-scale B_z.

Jonathan Hebert provided an update on his modeling of CTH discharges with applied loop voltage. Single-fluid MHD computations produce island structures when the edge iota is raised through low-order rational values, but the dynamics are not feeding back into the plasma-current evolution as they do in the experiment. He has diagnosed the behavior of the energy in groups of fluctuations, and there is a clear response as the edge iota hits rational values. Hebert has started looking into modeling with two-fluid effects. Suggestions from the audience include reexamining the anisotropic transport, possibly using O'Bryan's varying magnetization.

Nicholas Roberds described his approach to loading VMEC fields into NIMROD. The closed-flux and vacuum regions have to be treated separately. Roberds is using virtual casing to generate the vacuum-field contributions from the plasma current and adds that to the field from external coils. The flux surface and iota profiles for CTH tokamak-like equilibria in the NIMROD representation match those from VMEC. Roberds has tested different tokamak equilibria from VMEC and has reproduced internal and external kink modes.

Chang Liu is developing a hybrid simulation model to investigate the effects of runaway electrons on tearing instability. With the high runaway energies, a full-*f* system may be needed. The coupling with the majority species is through a current-based approach. The disparity of time-scales between the particle motion and the MHD is an important consideration, and particle sub-stepping may be used in the future. Initial testing is with a slab-geometry equilibrium that has a peaked current profile at the rational surface. In the nonlinear evolution, the runaway current becomes a nontrivial part of the total current.