External Kink Stability in NIMROD

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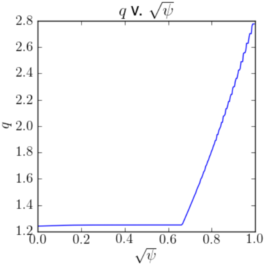
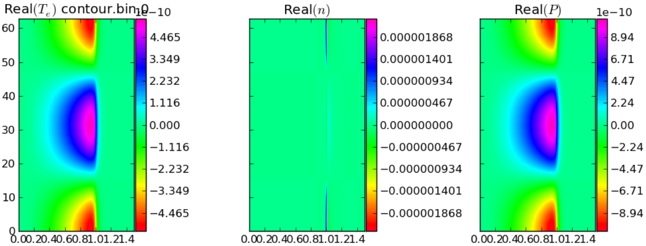
External Kinks are important for Vertical Displacement Event (VDE) evolution.

- External kinks occur during VDEs when plasma interacts with the surface, scraping off the edge region.
- The unstable modes are resonant ($q = m/n$) outside the plasma.
- Numerically resolving the instability in computations without a VDE help us understand what will be necessary for computations with a VDE.

We construct kink unstable equilibria in cylindrical geometry.

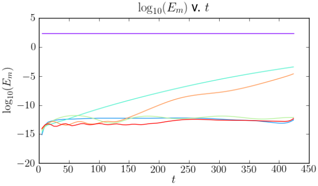
- To create a kink unstable equilibrium, we have the q profile near the plasma-vacuum boundary achieve a value consistent with a resonant surface. Initially, the q profile is shown to the right. The results for T, n, and p for a linear calculation are shown below.

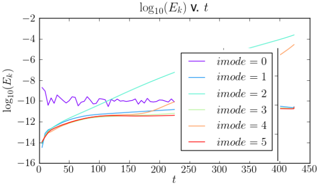




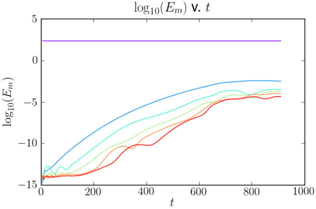
Trying different q values leads to different dominant modes.

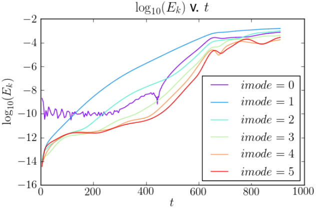
- With a $q = 2.35$ throughout the plasma, we get the log energy plots to the right.





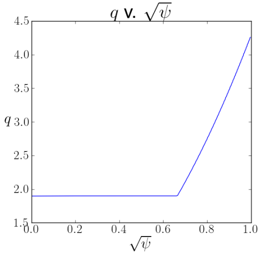
- With a $q = 1.8$ throughout the plasma, we get the log energy plots to the right.

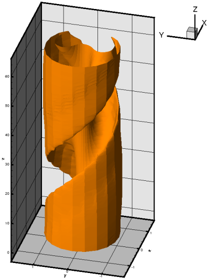




External kink unstable equilibria create noticeable plasma distortions.

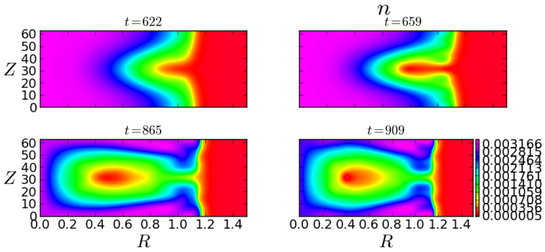
- Nonlinear cylindrical simulation results shows the shape of the distortion late in time ($t = 870\tau_{\mathrm{A}}$) for a large aspect ratio cylinder ($R/a = 10$). This is for the $q = 1.8$ case.



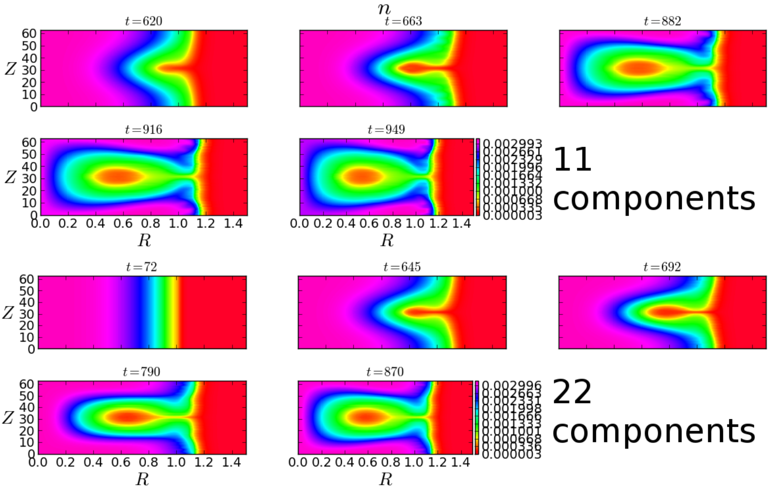


It is important to distinguish the plasma surface in the numerical representation.

- Too few Fourier components in the simulation cause Gibbs-like phenomena and cause the simulation to crash.
- Below is a low-resolution non-linear run with 6 Fourier components in the azimuthal direction. (Alfvén time units are used.)



The plasma is distinguished with sufficient numerical resolution

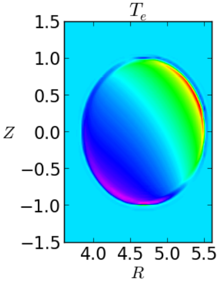


- We can see the instability, which looks like a vacuum bubble[1].

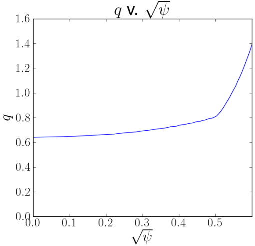
[1]Rosenbluth, Monticello, Strauss and White, Phys. Fluids **19** (1976)

We have also tested external kink dynamics in toroidal geometry.

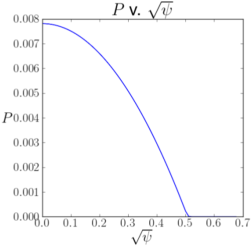
- Linear computation below shows the equilibrium being unstable to a $(1, 1)$ kink mode.
- The profile is also unstable to higher harmonics with $m/n = 1$.



Contours of constant temperature from the linear $n = 1$ eigenmode.



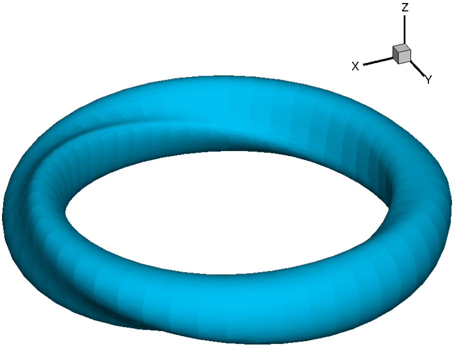
The q profile versus poloidal flux.



The pressure profile versus poloidal flux.

A nonlinear computation with the same equilibrium demonstrates external kink distortion in toroidal geometry.

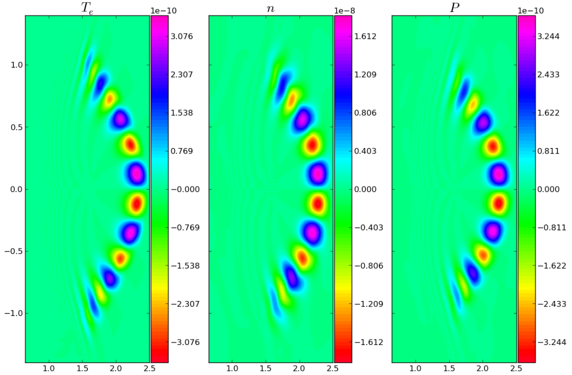
- Resistivity is determined by the evolving 3D temperature distribution.
- (2,2) and (3,3) components are large in this case.



Surface of constant pressure at $p(0)/8$ shows the plasma shape.

In toroidal geometry, other instabilities may arise, such as ballooning instability.

- The previous toroidal case had equilibria specially tailored to be external kink unstable.
- In realistic geometries other instabilities often arise. The double null case shown earlier exhibits a ballooning like instability.



Conclusions

- External kinks have been simulated in both cylindrical and toroidal geometry.
- External kink evolution requires sufficient numerical resolution of the plasma-vacuum boundary.
- External kink stability can be fairly well predicted based on the simple q-profile model.