High-Beta MHD Simulations of Toroidal Stellarators
NIMROD Team Meeting

T. A. Bechtel,  C. C. Hegna
University of Wisconsin - Madison

August 13, 2014
Outline

1. Purpose
2. Raising Rotational Transform
3. Heating
4. Preliminary Results
5. Future Work
Table of Contents

1. Purpose
2. Raising Rotational Transform
3. Heating
4. Preliminary Results
5. Future Work
To study magnetic topology evolution and plasma confinement in stellarators with heating and eventually flow sources.

Plan to extend the work of Mark Schlutt by:

- Increasing rotational transform without current drive.
- Studying high beta effects in toroidal, not helically symmetric plasmas.
- Investigating the effects of plasma flow.
# Table of Contents

1. Purpose
2. Raising Rotational Transform
3. Heating
4. Preliminary Results
5. Future Work
The Compact Toroidal Hybrid (CTH) is unique in that it has an axisymmetric vacuum vessel, but non-axisymmetric plasma. Equilibrium magnetic surface geometry is found using NIMROD by diffusing known magnetic fields at the vessel boundary through the computational domain.
Modifying the Equilibrium

- CTH has a $n = 5$ dominant plasma.

- Increasing the magnitude of these dominant modes at the boundary raises the rotational transform throughout the plasma and shifts plasma toward smaller major radius.

- Inward shift is counteracted by adding vertical ($n = 0, m = 1$).
Interesting Test Case 1

for all $n = 5$ modes multiply $B_r$ by 1.5
Interesting Test Case 2

for \( n/m = 5 \) modes multiply \( B_r \) by 1.5 and for \( n = 0, m = 1 \) mode multiply \( B_r \) by 2
Interesting Test Case 3

for $n/m = 5$ modes multiply $B_r$ by 2 and for $n = 0, m = 1$ mode multiply $B_r$ by 2.5
Interesting Test Case 4

for $n/m = 5$ modes add 5 to $B_r$ and for $n = 0, m = 1$ mode multiply $B_r$ by 2
# Table of Contents

1. Purpose
2. Raising Rotational Transform
3. Heating
4. Preliminary Results
5. Future Work
Method

- Heating source is implemented nearly identically to that used in Mark’s Thesis with the exception that heating is not applied to flux surfaces.
- Instead heat is applied to a circular cross section within the confined plasma.
- $k_{\parallel}/k_{\perp} \sim 10^5$ so heat is rapidly spread along surfaces to give smooth, radially peaked temperature and pressure profiles while closed flux surfaces exist.
Temperature Profiles

- Ion Temperature Profile
- Electron Temperature Profile

Temperature Profiles

Purpose
- Raising Rotational Transform
- Heating

Preliminary Results

Future Work
Heating Example: Case 4

- “High heating rate” of $16\text{MW}/m^3$ at center with heating profile linearly decreasing with radius.
- (VIDEO)
Island Analysis

Small \( m=4 \) islands appear early in evolution
Island Analysis (continued)

Islands flatten rotational transform as expected

![Graph 1: Islands flatten rotational transform](image1)

![Graph 2: Islands flatten rotational transform](image2)
Toroidal Transit

- New feature implemented in NIMFL
- (VIDEO)
- Instead of running NIMFL 100 times to get full Poincare surfaces for a full transit, it can be run once and only takes about 3 to 4 times longer
- Using a more modest 20 slices increases run time by around 10%
Short term:
- Test other heating rates.
- Try to raise rotational transform higher.

Long term:
- Add momentum source and study island effects.
Rotational transform is completely flat across core