Robustness an Flexibility in NCSX: Global Ideal MHD Stability and Energetic Particle Transport

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Introduction

- Study the effect of pressure and q profiles on stability and energetic particle transport.
- The VMEC, CAS3D and TERPSICHORE AND ORBITMN CODES are used.
- The QAS3_C82 design for NCSX, presented at EPS '99 is the initial baseline being examined.
- Kept boundary shape, $\langle\beta\rangle$, $\iota(0)$, $\iota(a)$ fixed.

Outline

1. Introduction: Description of C82 baseline equilibrium

2. Pressure and iota profiles being studied

3. Calculations

    - VMEC equilibria for 3.8% beta

    - TERPSICHORE global mhd instability

    - CAS3D global mhd instability

    - ORBITMN energetic particle transport

4. Summary and Future Work

Mode Selection Table for QAS Instabilities

- Tokamaks: toroidal modes are not coupled
- Stellarators: toroidal modes are coupled by magnetic field periodicity
- For stellarators, N_T=number of field periods,
- There are 1+[N_T/2] independent mode families for decoupled problems
- For three field periods, N_T=3,

  N=0 mode family includes vertical instability (n=0)

  and includes periodicity-preserving kink eigenmodes with

  n = ±/3, ±6, ±9...

  N=1 mode family includes external kink mode

  includes non-periodicity-preserving eigenmodes

  n = ±1, ±2, ±4, ±5, ±7, ±8...
- Iota ranges from 0.25 to 0.5, then resonant n/m ~ 4 to 2 allows a mode selection table to be constructed.

Pressure and Iota Profiles

- QAS3_C82 profile designated P00/I00
- P01 is analytic approximation to P00.
- P02 is steeper and P03 is broader than P01
- P04 is very broad H-mode like.
- P05 is Helias reactor profile based on W7X
- Iota(0) is fixed for all iota profiles.
- Iota(a) is fixed for all iota profiles except for I04 where it is above 0.5
- I01 and I04 are linear.
- I02 and I03 have edge shear increased to 1.5x and 2x the edge shear of I01.

Energetic Particle Transport

- Simulations carried out with deuterium beams and simple models for collisional effects of energy slowing down and pitch angle scattering.
- Injection radius was taken to be 1.3 meters for co-injected beams.
- Hydrogen beam losses are lower by ~30-40% with these collision models
- Optimization of injection angle can reduce losses by ~10%
- Calculations by Spong for NCSX (see Zarnstorff poster) with hydrogen beam losses and a more detailed collision model show even lower loss rates
- Sensitivity of energetic particle loss to the pressure and iota profiles will not depend on choice of beam isotope or collision models

Summary

- VMEC has been used to obtain 30 equilibria with different p and iota profiles, based on QAS3_C82
- TERPSICHORE has shown positional stability and kink stability for many of these cases
- CAS3D has extended TERPSICHORE results for C82 to show global mhd stability for this configuration even without a conducting wall. Further work with CAS3D should confirm the TERPSICHORE results with these pressure and q profiles, without a conducting wall.
- ORBITMN has shown quantitatively that with a given deposition profile, energetic particle transport changes little with these configuration changes
- Instability if grad P too large and too little shear.
- Tokamak intuition useful regarding MHD driving forces.
- When varying the NCSX pressure and iota profiles: improved stability is accompanied by only slightly increased particle losses.
- A startup P00/I00 plasma, β=1%: stable with reduced energetic particle loss.