COIL FLEXIBILITY COMPARISONS
I. OVERVIEW

N. Pomphrey NCSX Project Mtg, Sept 26-27, 2000.

- **"NCSX requires flexibility to study and achieve its scientific goals."**
- **Results presented in this session are to assess whether the Modular(M) coil design (LI383-A3) or Saddle(S) coil design (LI383-A4) show clear advantages over one another in their ability to control certain physics properties of NCSX.**
- **This comparative study provides an indication of the flexibility of NCSX coils. However, since this study uses only PRIMARY stellarator coils (designed to target the baseline plasma configuration), whatever flexibility we see from the present results will be improved in the final design after SECONDARY coils are added, such as Wayne's L=3 shear producing coils.**
- **In the comparisons, only <u>clear</u> differences should be regarded as significant, since results come from the optimizer. Final solutions can depend on assumed cost function weights and the strategy used to get there!**

To perform the Modular/Saddle assessment we have performed numerical experiments of two types:

1. **Coils are asked to maintain a fixed plasma shape as plasma conditions vary.**
2. **Coils are allowed to change the plasma shape as plasma conditions vary.**

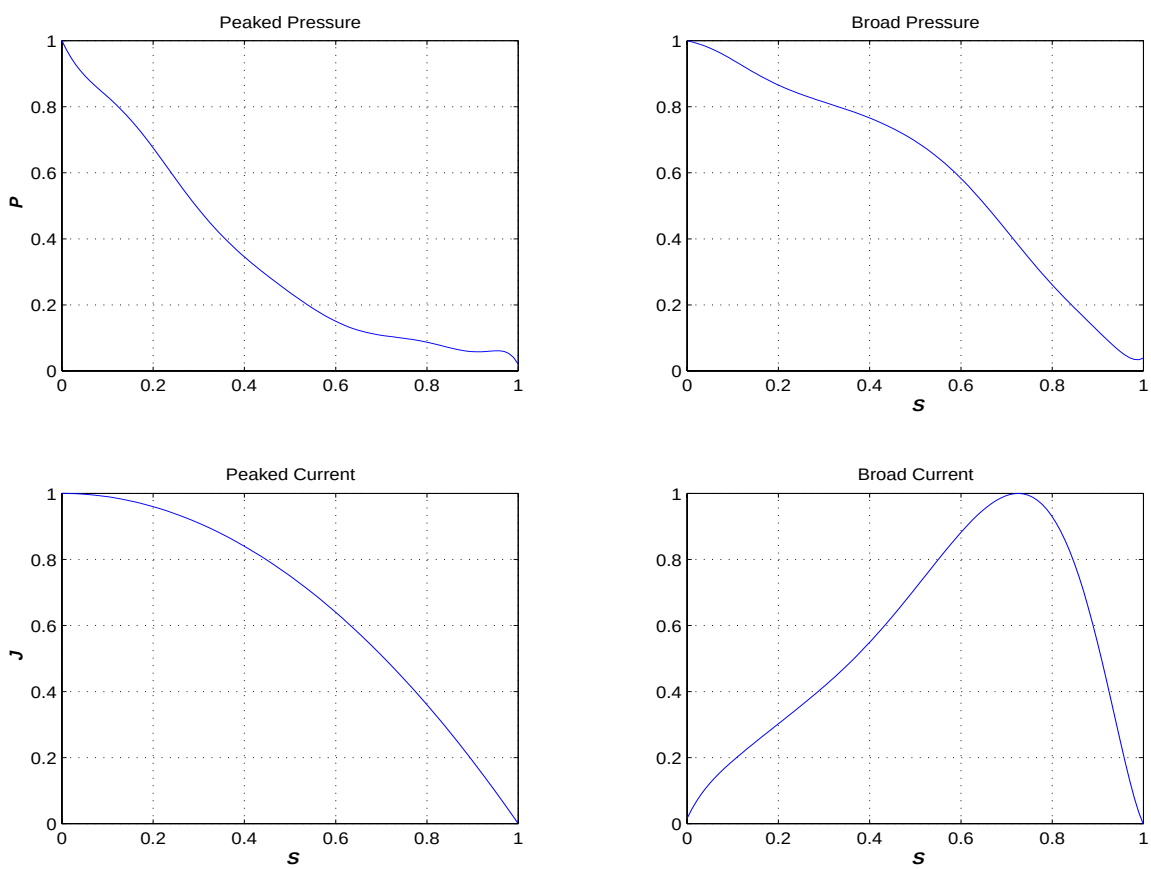
Ed Lazarus will discuss S1 $\rightarrow$ S2 $\rightarrow$ S3 discharge evolution simulations of Type 1, using plasma profiles obtained from TRANSP, with the LI383 fixed-boundary S3 plasma shape as the target plasma boundary. Note that tokamaks usually run in Type 1 mode, with a target shape in mind.

A number of Type 2 flexibility experiments have been performed by Ron Hatcher, Chuck Kessel and myself:

PLASMA PROFILE VARIATION:

For an assumed range of P and $< J \cdot B >$ profiles, using Modular and Saddle, ask: What is the optimum plasma performance?

We choose 2 pressure profiles (broad and peaked) and 2 current profiles (broad and peaked). For each of of the four Pressure/Current profile pairs (pp, pb, bp, pp), we vary coil currents in the free-boundary optimizer to optimize both transport and stability.



The "peaked" $p(s)$ is the PBX-M NBI shot included in D. Mikkelsen's database. The "broad" $p(s)$ is the CHS NBI shot in the same database. The peaked $< J \cdot B > (s)$ is analytic, of form $1 - s^2$. The broad $< J \cdot B > (s)$ is the baseline LI383 current profile.

For each profile pair we assume $I_p = 150$kA and target $RB_t = 2.05$ T-m. The plasma is constrained to be within, and tangent at some point, a 1st wall 3-D boundary surface.

We have run β-scans at $\beta = 1\%, 2\%$, and 3% to get an idea of the kink mode stability of optimized configurations, and have also exercised a new capability of the optimizer to vary β to find the β-limit while optimizing the transport. Both sets of results will be shown.

<u>IOTA-SCAN EXPERIMENTS:</u>

Here we compare the ability of the Modular and Saddle Coilsets to control the iota profile.

In one set of experiments we use the standard LI383 profile shapes corresponding to the fixed boundary S3 baseline configuration but lower β to 1%. Using S3 baseline free-boundary coil currents, the ι profile varies from $\iota(0) \approx 0.45$ to $\iota(1) \approx 0.65$. ie., the profile straddles $\iota = 0.5$. We ask whether the coilsets can modify the plasma shape at fixed RB_t in such a way that

(a) $\iota < 0.5$ everywhere, and

(b) $\iota > 0.5$ everywhere.

A motivation for such an experiment would be to test the influence of having the $\iota = 0.5$ surface within the plasma region.

We also would like to compare the ability of the modular and saddle coilsets to produce shear. In another comparative test we target

(a) a decrease in the shear, and

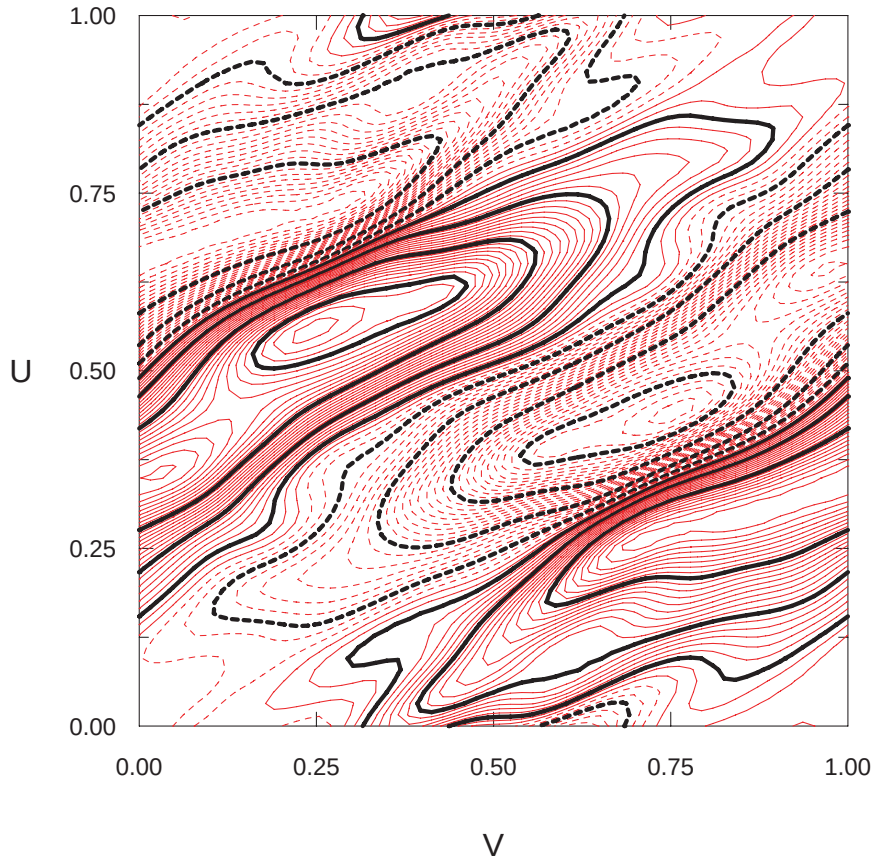
(b) an increase in the shear.

As in the previous iota-scan experiment, we use only the baseline plasma profiles.

COILS USED FOR COMPARATIVE STUDY

SADDLES:

We use the NESVD/GA LI383 coilset with 4 coils/half period ("coils.d1826.11.126.60.4").



MODULARS:

Coil set from Dennis Strickler, posted on 7/20/00 in /u/ftp/pub/abrooks/NCSX-COIL-DATA/li383/modular. Has 7 coils per period, giving 4 independent coil currents.

For each stellarator coilset, there are 4 independent coil currents. In the Results section, we will use I1, I2, I3, I4 to denote the currents in these coils. In the case of the Saddles, coil "1" is the longest saddle; coil "4" is the shortest saddle (see contour plot).

All currents shown are normalized to the values which support the S3 free-boundary baseline plasma.

For the Modulars, a pure axisymmetric TF coil is added to the coilset so that as the individual modular coil currents are varied, the average toroidal field can remain constant. This TF coil current is named ITF, and a negative number corresponds to the production of toroidal flux. In the case of Saddles, the TF current is held fixed as the saddle currents vary.

The stellarator fields are supplemented by axisymmetric fields for additional control. In the results I will present, the axisymmetric fields are in the form of a Dipole, Quadrapole, Hexapole, and Octapole field. These multipole fields are expanded around $R = 1.7$m, and are in units such that $\mu_0 B_0 = 1$. In Ed Lazarus's presentation, the supplementary axisymmetric fields are supplied by a particular set of PF coils.