132-090729-PHT-01

Memo to Bob Woolley
From: Peter Titus
Subject: Maximum TF Torsional Shear

References:
[1] Woolley memo # 13-260709
[2] Provisions for Out-of-Plane Support of the TF Coils in Recent Tokamaks P.Titus, Applied Superconductivity Conference, September 26 1999, Volume 10 Issue 1, Pages 635-640

Your moment calculations (CALC-132-03) are elegant and will be useful to find the maximums in Charlie's spreadsheet –

The summation of the outer leg moment is directly useful in evaluations of the up-down asymmetric case that Han is running in the diamond truss/tangential - radius rod calculations.

An upper half vs. lower half of the outer legs would be useful in that those loads are either to be equilibrated through the diamond truss or the tangential radius rods and vessel.

A moment summation of the upper half vs lower half of the tokamak is not useful because the stiffness of the structure will determine how much torque goes to the central column and how much goes to the outer TF and vessel structures.

A very useful calculation would be the build-up of torsional shear in the TF inner leg. I believe you can easily calculate this by summing the torsional moment from the bottom to positions along the height of the central column. This would give torque distribution and a total torque on the central column. You could assume the total torque is reacted equally by the top and bottom umbrella structure domes or diaphrams. Then divide by the distribution by the torsional resistance factor to get the shear stress. This could readily be implements in Charlie's system analysis program.

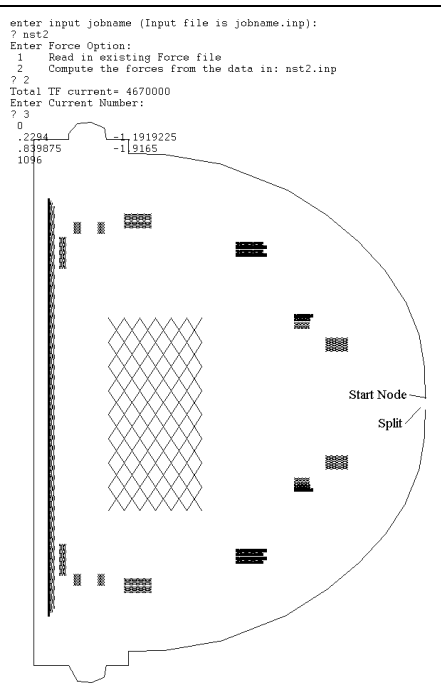

Figure 1 NSTX Shell Model

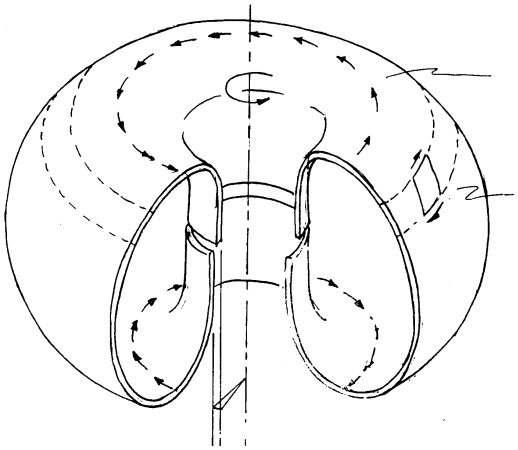

Figure 2 Simple Toroidal Shell Model. OOP loads are computed from the TF current and PF currents using an elliptical integral solution for the PF fields. TF OOP loads are assumed to be applied to a toroidal shell – with varying thickness to simulate more complex OOP structures. Shear deformations are accumulated to a split in the shell, then a moment is applied to align the split.

The distribution of torsion along the height of the TF central column is needed because there are torsional stress reversals in the central column that you won't see if you just sum the moment on the central column. These are evident in Figure 3 for the IM and equilibria results.

I am including some results of the torque shell program I described in earlier notes and which is documented in ref[2]. The results presented are for the OH on only, and the "squareness" equilibria . These analyses produced a -17.7 MPa torsional shear for IM and about 4 MPa for the equilibria. Figure 4 shows the results for the inner leg torsional shear stress from the global model, which is currently in process and the shell model. Figures 5 through 10 are some additional results for the .1 squareness equilibria

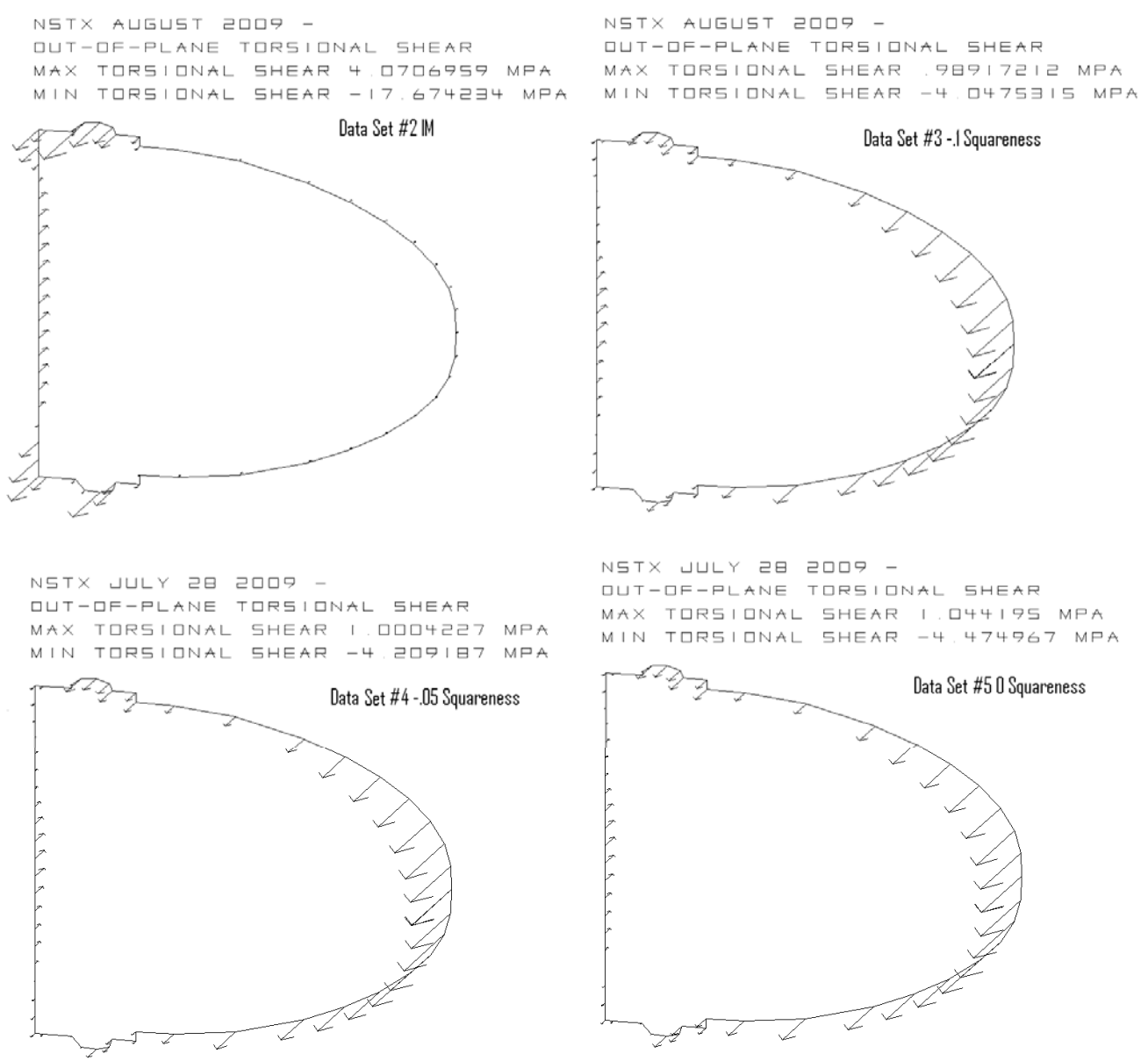

Figure 3 - Torsional Shear for IM and some Equilibria

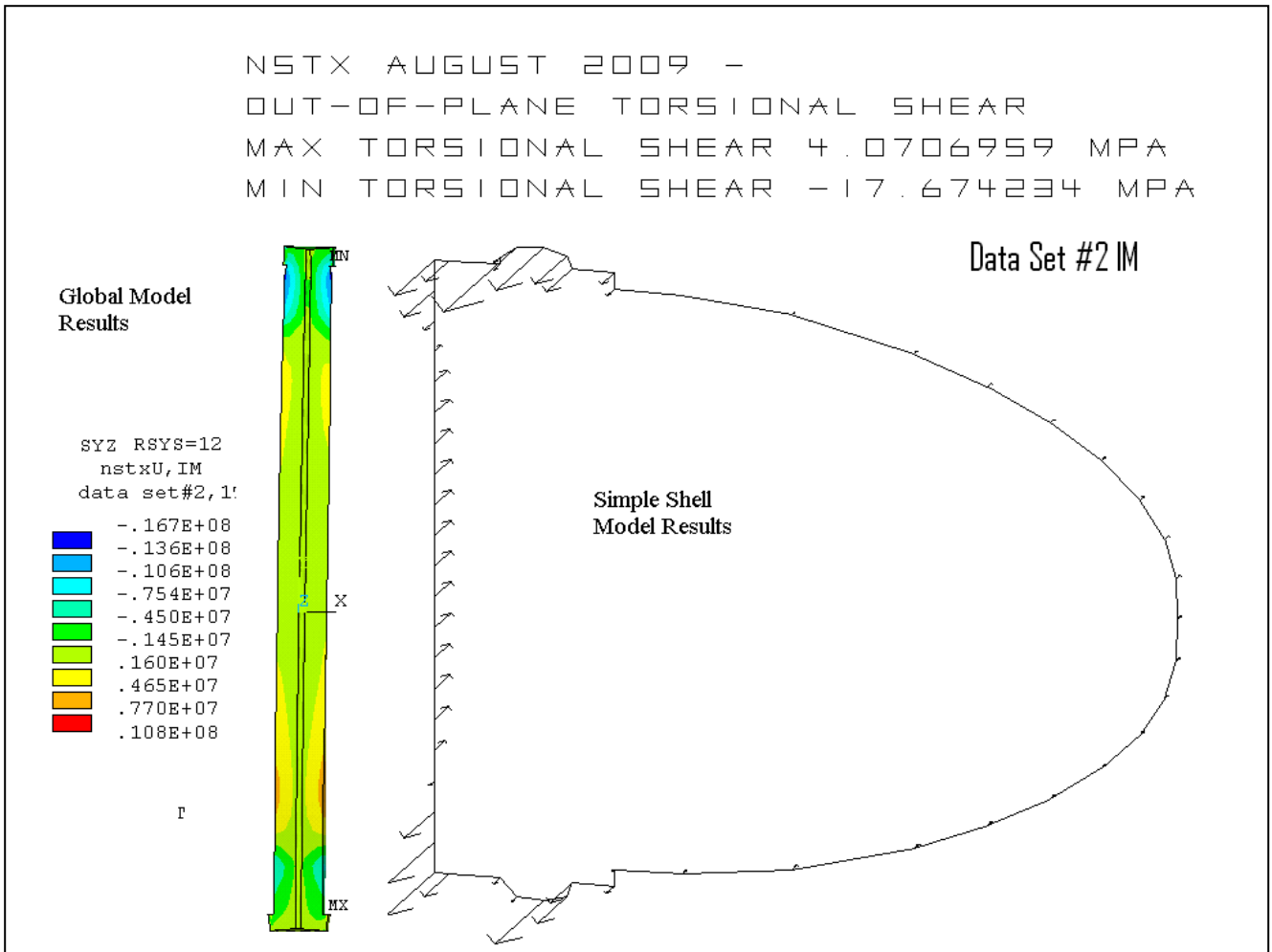

Figure 4 - Comparison of Global FEA and Simple Shell Analyses

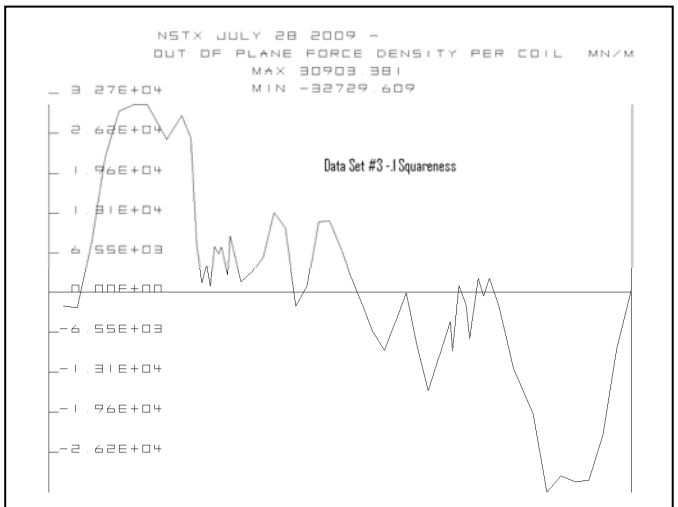

Figure 5 - OOP Force Density Along TF CL starting from Outboard Equatorial Plane

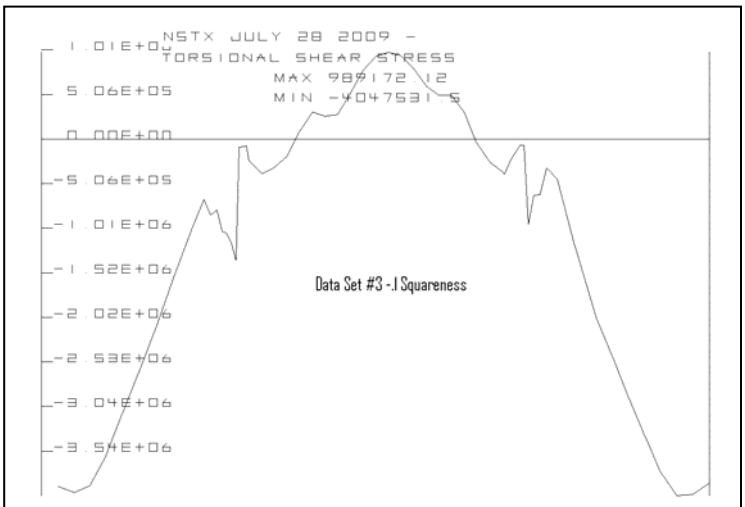

Figure 6- Torsional Shear Stress Along TF CL starting from Outboard Equatorial Plane

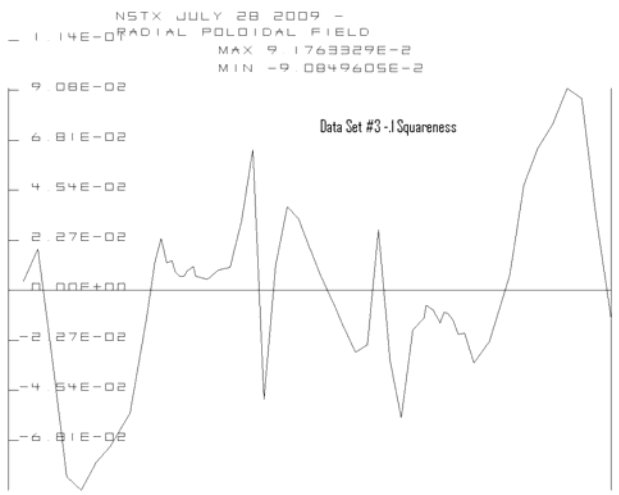

Figure 7 Radial Polidal Field

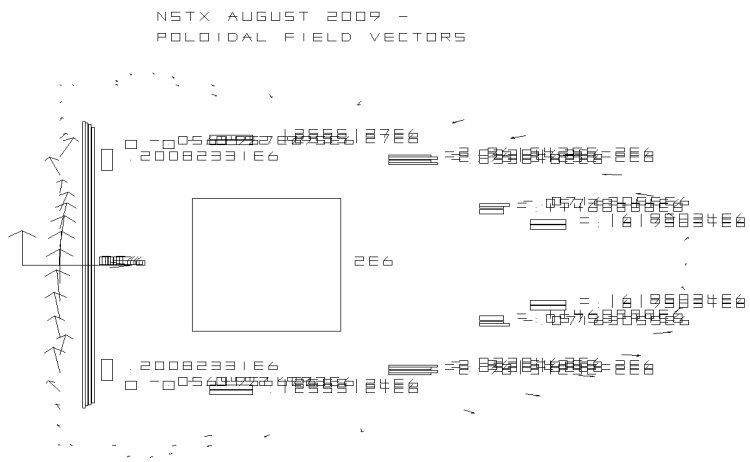

Figure 8 Poloidal Field Vectors, Coils, and Currents

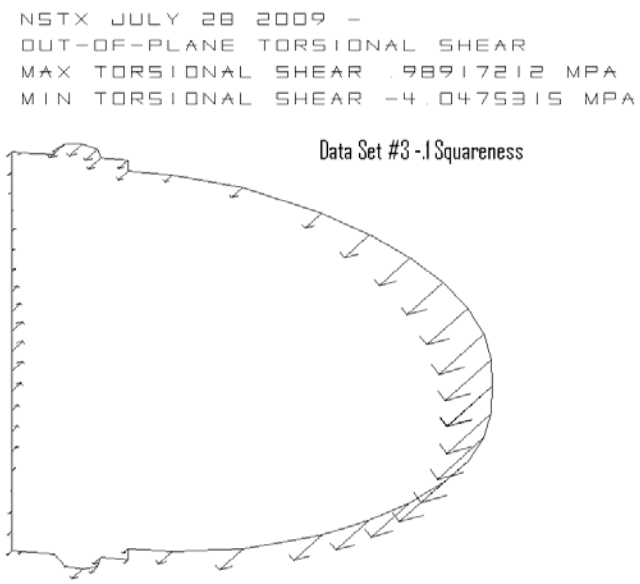

Figure 9 Out-of-Plane torsional shear

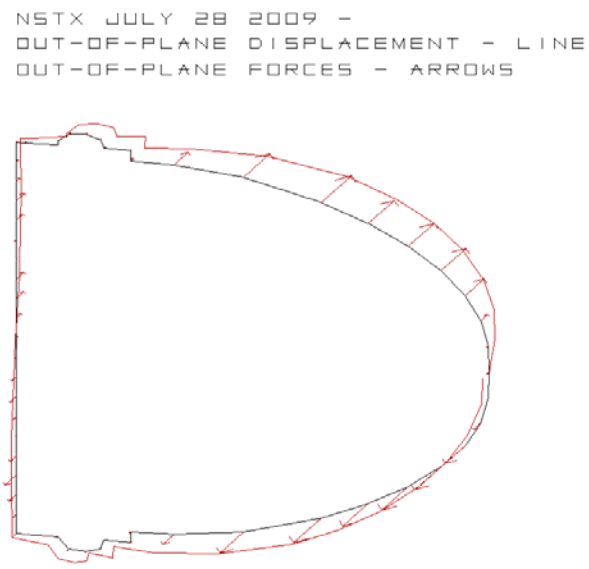

Figure 10 Out-of-Plane Displacements and Out of Plane Forces