Stellarator Equilibrium Reconstruction: V3FIT

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Equilibrium reconstruction is the process of inferring the radial profiles of an MHD equilibrium model by minimizing the mismatch between model-calculated and observed diagnostic signals. Axisymmetric equilibrium reconstruction, as exemplified by the EFIT code[1], has proven invaluable for the interpretation of tokamaks and RFPs. V3FIT is a non-axisymmetric equilibrium reconstruction code, based on the VMEC stellarator equilibrium code[2].

V3FIT (like most inverse problems) infers the parameters by minimizing a cost function that is quadratic in the signal misfits:

$$g^2(p) \equiv \sum_i w_i \left(\frac{S_i^o - S_i^m(p)}{\sigma_i} \right)^2$$

where p is a vector of parameters, $S^{o(m)}$ is an observed (model-computed) signal, σ is a normalizing factor, and w a weight. V3FIT currently minimizes g^2 by using Newton's algorithm to find the location in parameter space where the slope of g^2 is zero, using a Singular Value Decomposition of the finite-difference approximation to the Jacobian matrix

$$J_{ij} \equiv \frac{\partial S_i^m}{\partial p_j}.$$

An evaluation of model signals requires the convergence of the VMEC equilibrium code. The V3FIT reconstruction algorithm is tightly coupled to the VMEC convergence, since the small steps in parameter space are accomplished by changing the VMEC parameters for an already converged VMEC equilibrium, and further converging VMEC. Thus VMEC, after its first convergence, does not have to convergence very far as the reconstruction algorithm proceeds.

V3FIT results will be shown for reconstructions of stellarator equilibria with magnetic diagnostic signals and interferometer/polarimeter signals. The reconstruction results match closely the expected behavior when Gaussian noise is added to the simulated observed signals. Comparisons of V3FIT reconstructions with EFIT reconstructions will also be shown for experimental data from the DIII-D tokamak.

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