A COMPARISON OF OPTIMIZATION-BASED APPROACHES FOR A MODEL COMPUTATIONAL AERODYNAMICS DESIGN PROBLEM. Paul D. Frank and Gregory R. Shubin, *Boeing Computer Services, MS 7L-21, P.O. Box 24346, Seattle, Washington 98124-0346, U.S.A.*

The objective of this paper is to compare three optimization-based methods for solving aerodynamic design problems. We use the Euler equations for one-dimensional duct flow as a model problem. The optimization methods are (i) the black-box method with finite difference gradients, (ii) a modification where gradients are found by an algorithm based on the implicit function theorem, and (iii) an all-at-once method where the flow and design variables are simultaneously altered. The three methods are applied to the model problem and compared for efficiency, robustness, and implementation difficulty. We also show that the black-box (implicit gradient) method is equivalent to applying the "variational" or "optimal control" approach to design optimization directly to the discretized analysis problem, rather than to the continuous problem as is usually done. The black-box method with implicit gradients seems to provide a good compromise of features and can be retrofitted to most existing analysis codes to turn them into design codes. Although the all-at-once method was found to be less robust than the black-box methods, when it succeeded it was considerably more efficient.

A NUMERICAL TECHNIQUE FOR OBTAINING THE COMPLETE BIFURCATED EQUILIBRIUM SOLUTION SPACE FOR A TOKAMAK. F. J. Helton and J. M. Greene, *General Atomics, San Diego, California 92138-5608, U.S.A.*

This paper describes a new numerical method for finding solutions to the ideal MHD equilibrium problem. The space of solutions thus found can have more than one bifurcation branch, depending on the tokamak being modeled. We suggest that the solutions which are difficult to obtain without the use of this technique correspond to equilibria which are difficult to maintain in the tokamak being modeled. First, this paper investigates, for a tokamak design with large poloidal field-shaping coil (PFC) to plasma distance, the bifurcated numerical solution curve as a function of flux loop position and relates this curve to the practical existence of ideal magnetohydrodynamic equilibria and practical tokamak design In previous papers, some of the problems which could arise for large PFC–plasma distance were discussed. Then, using a *regularization* technique, it was shown that, for large PFC–plasma distance, the flux loops should be close to the PFCs for stable control if the full information from the flux loops is used. Here it is shown that, for large PFC–plasma distance, the structure of the equilibrium solution space becomes increasingly complex and desirable solutions become more difficult to attain as the flux loops are moved farther from the plasma. In order to explore this solution space numerically, it is necessary to obtain solutions for which the usual Picard iteration method is unstable. Here an extension of this method is given. The solution space is enlarged by adding additional variables and constraints, so that the iteration to the desired solution is stable in the extended space. A modified version of this numerical technique has been used to obtain equilibrium fits to highly elongated DIII–D plasmas. The numerical equilibria are very difficult to obtain without the use of this technique and the plasmas are difficult to maintain in the tokamak.

NUMERICAL ANALYSIS OF 2D MHD EQUILIBRIUM WITH NON-INDUCTIVE PLASMA CURRENT IN TOKAMAKS. K. Tani and M. Azumi, *Japan Atomic Energy Research Institute, Naka-machi, Naka-gun, Ibaraki-ken, JAPAN 311-01;* R. S. Devoto, *Lawrence Livermore National Laboratory, P.O. Box 5511 Livermore, California 94550, U.S.A.*

We have developed a numerical code to investigate steady state neutral-beam-driven, Ohmic, and bootstrap currents which are consistent with MHD equilibrium. The code can describe the effects of mirror trapping, energy diffusion, and bounce motion of fast ions on the beam-driven current. The bootstrap current is evaluated for multi-species ions including impurity and unthermalized fast ions An iterative algorithm is employed to obtain a self-consistent current and MHD equilibrium. MHD stability for the converged solution can also be investigated with the code.