BOOK REVIEW

Selection of books for review is based on the editor's opinions regarding possible reader interest and on the availability of the book to the editor. Occasional selections may include books on topics somewhat peripheral to the subject matter ordinarily considered acceptable.

Numerical Simulation and Optimal Control in Plasma Physics with Applications to Tokamaks

Author	Jacques Blum
Publisher	John Wiley & Sons, Inc., New York, New York (1989)
Pages	363
Price	$77.95
Reviewer	Stephen C. Jardin

This unique book concerns itself with the magnetohydrodynamic (MHD) description of the tokamak equilibrium state and its self-consistent time evolution. The particular emphasis is on modeling, numerical simulation, and optimal control.

The development of these topics is very systematic, leading from an abstract mathematical formulation to some very practical applications dealing with specific tokamak devices. The level of mathematical rigor is consistently high, with a large number of theorems, propositions, lemmas, and proofs.

The first chapter covers the MHD equilibrium problem itself. Particular emphasis is on the correct formulation of the problem, both in its strong and weak forms, and on the nonlinearities arising from the plasma current, the free boundary of the plasma, and the magnetic permeability of adjacent iron structures. A discrete representation using finite elements is presented. Linearization is discussed and used in analyzing the convergence properties of five algorithms for numerically iterating the solution for the full nonlinear problem. Real examples are given of the success of these methods in calculating equilibrium in the Joint European Torus, Tokamak Fontenay-aux Roses (TFR), Tore Supra, and International Tokamak Reactor (INTOR) tokamaks.

Chapter II is concerned with the problems of static control; that is, the determination of the magnitude of the currents in the tokamak poloidal field coils, which give the plasma the desired position and shape. This is treated in terms of optimal control of a distributed parameter system by the introduction of control parameters, equations of state, and cost functions. Numerical methods of solution are discussed, and a number of examples are presented where these methods have been applied to real tokamak experiments.

Chapter III treats the question of the mathematical existence of solutions to a simplified model problem in which the equilibrium operator becomes linear. An important existence theorem by Temam is extended by the Leray-Schauder method of topological degree.

Chapter IV is devoted to a most interesting technique for determining the radial stability properties of tokamaks with iron. The method consists of examining the bifurcation properties of equilibrium, as a continuous parameter λ measuring the coil current distribution is changed. A detailed description of the application of this method to the TFR tokamak is presented.

Chapter V deals with the boundary identification problem of how to identify the shape and location of the plasma vacuum interface from a set of external magnetic measurements. Two substantially different methods are discussed. One involves solving the elliptic equation for the vacuum magnetic field in the region between the plasma boundary and the surface where the measurements are known. The other involves making a parametric identification of the plasma current density.

Chapter VI covers the theory of what is now known as $1\frac{1}{2}$-dimensional transport. This consists of the derivation of a set of surface-averaged transport equations for the plasma fields and thermodynamic quantities. Iterating between the solution of these transport equations and the two-dimensional elliptic equation for the equilibrium yields a coupled system of equations describing the transport time scale evolution of plasma equilibrium.

Finally, Chapter VII uses standard large aspect ratio tokamak ordering to develop a greatly simplified description of the evolution of a circular tokamak. This simplification allows the approximate plasma transport and equilibrium equations to be coupled together and solved numerically in a very efficient manner. Interesting examples are given of this simplified system applied to the TFR tokamak.

On the whole, this book is remarkable in both its scope and its rigor. It deals with many topics essential for the operation of a modern tokamak and presents much new material on their mathematical foundations that will not be found elsewhere. Anyone working in the fields of tokamak control, equilibrium, or transport would find this book an invaluable resource.

Dr. Stephen C. Jardin received his education at the University of California, Berkeley (BS, engineering physics, 1970), Massachusetts Institute of Technology (MS, physics, and MS, nuclear engineering, 1973), and Princeton University (PhD, astrophysical sciences, 1976). He has been at the Princeton Plasma Physics Laboratory since 1976 and is now principal research physicist and lecturer with rank of professor.