MAGNETIC FLUX RECONSTRUCTION
METHODS FOR SHAPED TOKAMAKS

by

CHI-WA TSUI

Submitted to the Department of Nuclear Engineering
on December 1, 1993, in partial fulfillment of the
requirements for the degree of Doctor of Philosophy

ABSTRACT

The use of a variational method permits the Grad-Shafranov (GS) equation to be
solved by reducing the problem of solving the 2D non-linear partial differential
equation to the problem of minimizing a function of several variables. This high
speed algorithm approximately solves the GS equation given a parameterization of
the plasma boundary and the current profile (p' and FF' functions). We treat the
current profile parameters as unknowns. The goal is to reconstruct the internal
magnetic flux surfaces of a tokamak plasma and the toroidal current density profile
from the external magnetic measurements. This is a classic problem of inverse
equilibrium determination. The current profile parameters can be evaluated by
several different matching procedures. We found that the matching of magnetic
flux and field at the probe locations using the Biot-Savart law and magnetic Green’s
function provides a robust method of magnetic reconstruction.

The matching of poloidal magnetic field on the plasma surface provides a
unique method of identifying the plasma current profile. However, the power of
this method is greatly compromised by the experimental errors of the magnetic
signals. The Casing Principle [60] provides a very fast way to evaluate the plasma
contribution to the magnetic signals. It has the potential of being a fast matching
method. We found that the performance of this method is hindered by the accuracy
of the poloidal magnetic field computed from the equilibrium solver.

A flux reconstruction package have been implemented which integrates a vac-
uum field solver using a filament model for the plasma, a multi-layer perceptron
neural network as a interface, and the volume integration of plasma current density
using Green’s functions as a matching method for the current profile parameters.
The flux reconstruction package is applied to compare with the ASEQ and EFIT
data. The results are promising. Also, we found that some plasmas in the tokamak
Alcator C-Mod lie outside our operationally valid region, given the current set of the trial functions inside the variation method.

Thesis Supervisor: Ian H. Hutchinson, Jeff P. Freidberg
Title: Professors of Nuclear Engineering