Surface Current Equilibria for a Stellarator

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The work presented here is focused on the calculation of 3-D stellarator equilibria using the well-known surface current model which assumes that all plasma current flows only on a single surface $r = r_s(\theta,\phi)$. The pressure within the surface is a constant and both the interior magnetic field plus external magnetic field just outside the surface satisfy the vacuum Maxell's equations. The model has been investigated for both equilibrium and stability for arbitrary 2-D tokamak shapes [1]. It has also been used to investigate 3-D stellarator equilibrium and stability in the context of the large aspect ratio stellarator expansion [2]. A recent 3-D multi-surface stellarator model has been developed for computing equilibria and is largely focused on the interior solution [3]. The contribution of the present work is to extend these studies to solve both the interior and exterior problems for a single 3-D surface model that is valid for arbitrary $\beta, \iota_H, \iota_I, \varepsilon,$ and $r_s(\theta,\phi)$. The main advantages of the model are (1) a crisp separation of equilibrium and stability, (2) reduction of the analysis to an exact 2-D formulation, (3) evaluation of both equilibrium and stability MHD β limits, and (4) optimization of plasma shape for high performance with respect to large scale external MHD modes. The model obviously does not treat internal pressure gradient driven modes, nor take into account neoclassical transport. Another application of the model is the examination of 3-D tokamak equilibrium perturbations with the aim of optimizing disruption free operation.

The strategy of our equilibrium analysis is to calculate the interior fields on the plasma surface by means of a fast 3-D Green's function procedure. The fields just exterior to the surface require the solution to a first order, quadratically nonlinear partial differential equation, which is obtained by the method of characteristics. These fields are all that are needed to completely determine plasma stability limits. The present work, however, solely focuses on equilibria.

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