Methods of describing magnetoplasma systems

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C. Mercier. Lectures in Plasma Physics, Commission of the European Communities and Monotopia Franchi, Citta di Castello, Italy, 1987, pp. 241.

In research on controlled thermonuclear fusion the major direction is associated with retaining a high temperature plasma in toroidal magnetic systems of the type of tokamaks and stellarators. This problem is based on the theory of equilibrium and MHD stability of toroidal magnetoplasma configurations. The author of the book under review is a French theoretician who is well known to specialists by his pioneering work laying down the foundations in the field of MHD plasma theory.

This book is a second expanded edition of Mercier's lectures with the same title (1974). The title as given above is too general. The subject matter of the book is more accurately reflected in its subtitle "Magnetohydrodynamic Description of Plasma Confinement in Closed Magnetic Configurations", i.e., these are lectures on one quite narrow, but important section of plasma physics, the MHD theory of equilibrium and stability of toroidal magnetoplasma configurations. The contents of the book are preceded by an introduction by the German plasma physicist A. Schlüter and a preface by the author to the present and the first editions.

The first chapter of the book presents general ideas concerning toroidal magnetic systems. Definitions of toroidal and poloidal magnetic fluxes in a general toroidal geometry, the rotational transformation, etc., are introduced. A new addition to this chapter compared to the first edition of the book is section 1.4 in which an original method of investigating the "island" structure of magnetic surfaces is presented, and concrete examples are given.

The second chapter presents the method of investigating the MHD stability using the example of the cylindrical case. Then a method is described of investigating the MHD local instability of the "first kind" (the Mercier criterion) and of the "second kind" (the balloon modes). The terminology "first and second kind" was introduced by the author in the first edition even prior to the development of a complete theory of instability of the balloon modes setting a restriction on the limiting pressure of the plasma confined stably in a given configuration. It should be noted that the author presents primarily his own results and, unfortunately, did not include in the chapter the important results of numerous numerical calculations of the limiting pressure of plasma in tokamaks and stellarators.

The third chapter of the book is devoted to some approximate analytical methods of solving the equilibrium equations—expansion in powers of the distance from the magnetic axis, expansion in terms of the curvature of the magnetic axis, the method of the "helical image". The first two methods are applied quite widely, the third has been used by the author for studying the equilibrium near perturbed "rational" magnetic surfaces (with magnetic lines of force closing in on themselves). In terms of parameters describing equilibrium this chapter gives the Mercier criteria for the near-axis region of configurations with non-zero ellipticity and with triangular sections of magnetic surfaces and for systems with circular sections of magnetic surfaces.

The last, fourth chapter of the book is devoted to a description of the equilibrium of plasma in the case of axial symmetry. Examples are given of exact solutions of the internal problem. In the case of a circular section of the plasma the solution of the external problem is also examined. The presented expansion of the solution near a given magnetic surface is original. For plasma with a circular section diagrams are presented of the local MHD stability of the plasma taking the effect of the balloon modes into account. The end of the chapter contains an example of calculating the condition for the local stability of the plasma in the case of a tokamak with a "bean-shaped" cross section.

On the whole the book is of interest not so much because of its concrete results of investigations of equilibrium and stability of a toroidal plasma (from this point of view it is not at the level that has been achieved elsewhere), but more because of its presentation of methods of analytical description. Therefore the book should be regarded not as a means of expanding the horizons of a wide circle of readers, but basically as an aid for investigators involved with problems of the theory of equilibrium and stability of toroidal magnetohydrodynamical stystems.

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