Theory of diamagnetic signal in current-free stellarators

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The toroidal magnetic flux through the plasma column is calculated analytically for current-free stellarators of arbitrary geometry. This is done with accuracy sufficient to extract the contribution into the magnetic flux due to the finite plasma pressure. The final result is the formula relating the measured diamagnetic signal with β, the ratio of the plasma pressure to the magnetic pressure. This formula can be used for diagnostic purposes in stellarators of any type. For example, in the Large Helical Device with planar circular axis [1] or in the helical axis stellarator Heliotron J [2, 3].

The calculations are based on the explicit general expression [4] for the equilibrium current density $\mathbf{j}$ satisfying both the force balance and the current continuity equations, $\nabla p = \mathbf{j} \times \mathbf{B}$ and $\mathrm{div}\,\mathbf{j} = 0$. For current-free toroidal plasma this expression can be integrated in a general form without any assumption on the plasma shape, aspect ratio, etc. Two assumptions are only needed then to derive the final relation: β value and the relative depth of the magnetic well are small. These are natural conditions for stellarators, therefore the final result can be recommended for magnetic diagnostics without practical limitations.

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[2] T. Obiki*,* T. Mizuuchi, K. Nagasaki*, et al.,* Nucl. Fusion **41** (2001) 833

[3] S. Besshou, K. Aizawa, K. Tomiyama *et al*., Rev. Sci. Instrum. **72** (2001) 3859.

[4] V.D. Pustovitov, *Reviews of Plasma Physics*, edited by B.B. Kadomtsev and V.D. Shafranov (Consultants Bureau, New York, 2000), Vol. 21, p. 1.