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Analytic anisotropic-pressure equilibria with incompressible flow in helically symmetric geometry

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It is shown that the equilibrium states of an MHD helically symmetric plasma with incompressible flow and pressure anisotropy are governed by a generalized Grad - Shafranov equation for the helical magnetic flux containing six surface quantities together with a Bernoulli equation for an effective isotropic pressure defined as $\bar{p} = (p_{||} + p_{\perp})/2$, where $p_{||}$ and $p_{\perp}$ are the CGL pressure tensor elements parallel and perpendicular to the magnetic field [1]. This equation recovers the respective ones that govern both axisymmetric and translationally symmetric equilibria, either with pressure anisotropy and flow or not, as particular cases [2-4]. The form of the generalized equation indicates that the parallel flow, expressed by a poloidal Alfénic Mach function and the pressure anisotropy measured by the function $\sigma_d = \mu_0(p_{||} - p_{\perp})/B^2$ assumed to be uniform on the magnetic surfaces, have a cumulative impact on equilibrium in agreement with [3] for the axisymmetric case. In addition, through the most general linearizing ansatz for the free functions included in the derived Grad - Shafranov equation, we construct equilibrium solutions and study their properties. It turns out that the pressure anisotropy has a paramagnetic effect for $\sigma_d > 0$ and a diamagnetic one for $\sigma_d < 0$, irrespective of the shape of the helical current density profile, though the latter profile is noticeably affected by the pressure anisotropy. Also, the parallel flow induces paramagnetism, while the nonparallel one associated with the electric field induces diamagnetism. The generalized equation and its solutions obtained in the present study, being two-dimensional in connection with configurations of constant torsion and without toroidicity, consist a first step approximation to the actual steady states of stellarators. In this respect, they can contribute to modeling such a large aspect ratio device, as that described in [5].

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