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Two-Fluid Effects on Stability and Beta Limits in 3D Configurations

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Abstract

Two-fluid plasmas, with independently evolving fluid electron and ion species connected through quasineutrality, can generate steady state flows in non-axisymmetric configurations, sustained by the equilibrium pressure gradients, but smaller than the diamagnetic drifts. These flows can have stabilizing effects on the pressure-driven instabilities that set one important limit on the maximum plasma beta. Starting from an ideal MHD equilibrium configuration (eg, calculated by the VMEC code) with zero plasma mass flow $\mathbf{v}_i = 0$, two-fluid flows develop rapidly on an MHD time scale, some few tens of shear Alfvén times, in the region of strong equilibrium pressure gradient. They persist over times long compared to the scales of MHD and the relaxation of the initial configuration Two fluid effects can favorably influence the stability of high and moderate mode number localized ballooning instabilities through shear flow stabilization. They can also affect the rate of magnetic reconnection occurring at mode rational surfaces, depending on the ratio of the electron and ion pressures and plasmas with higher ratios of the electron to ion pressure may have larger steady state islands (in the absence of neoclassical effects). Illustrations are given for stellarators, using the nonlinear two-fluid model in the massively parallel M3D code [1]. In the high beta, quasi-axisymmetric NCSX design, ballooning stability limits may be raised significantly above the nominal design value calculated from linear stability codes.

[1] L.E. Sugiyama and W. Park, *Phys. Plasmas* **7** 4644 (2000).