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Electron Heat Confinement in Reversed Field Pinches *

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Abstract

We present predictions for electron heat confinement times in Reversed Field Pinches (RFPs) using two different closures for the parallel electron heat flow in the plasma electron energy equation. The first model relates $q_{\|}$ to the local parallel gradient in electron temperature multiplied by a large ($> 10^5$) effective parallel conductivity to capture qualitatively the large anisotropy between electron heat flow parallel vs. perpendicular to the magnetic field in moderately collisional plasmas. The second model uses an integral closure[1] that gives electron heat flow along the magnetic field for arbitrary collisionallity. Unlike the diffusive closure which only uses the local temperature gradient to calculate heat flow, the integral closure involves temperature perturbations with multiple scale lengths along the magnetic field. We show that since the diffusive closure depends on a single scale length, it underestimates the parallel electron heat flow in plasmas with multiple scale lengths such as those present in the chaotic magnetic field structures of some RFP discharges.

We use the high-order element version of the plasma fluid code NIMROD[2] to calculate effective electron heat diffusivities utilizing the two closure schemes. One calculation is done in a magnetic field characterized by large amounts of field line chaos. We evolve the flow and magnetic field to a steady state, and then keeping the flow and magnetic field fixed, evolve the electron energy equation with a resistive heating term. Using the steady-state electron temperature profile (which is appropriate since the resistive time is long compared to the parallel transport timescale), we then calculate effective electron heat diffusivities and compare with analytical results from Rechester and Rosenbluth[3]. The second calculation is done in a magnetic field that resembles those seen in RFPs when edge current drive is used to mitigate the effects of micro-tearing instabilities leading to improved electron heat confinement. We effect this by simply turning down the amplitude of the modes causing our chaotic field. The heat diffusivities we calculate using the two closure schemes in this magnetic field are then compared to results of O'Connell et al..[4] We show that the integral closure more accurately predicts electron heat flow in plasmas with multiple gradient scale lengths. We also comment on numerical stability, feasibility and scalability properties of the implementation of the integral closure in the NIMROD code.

References

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*Research supported by the U.S DOE under grant no. DE-FG03-01ER54618.