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Pressure balance in a low collisionality tokamak scrape-off layer

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Understanding the physics governing the scrape-off layer is necessary in order to reliably predict machine and operation critical quantities, such as the heat flux width at the divertor, plasma-wall interaction, material migration, effect of divertor condition on the pedestal profile, etc. Among the most basic quantities to predict is how the density and temperature in the SOL change from an upstream location to the divertor target.

Recent simulation results [1,2] using the axisymmetric gyrokinetic code XGCa showed several noteworthy features for a low-collisionality discharge of the DIII-D tokamak. Comparisons of the electron pressure variation in the divertor region between simulation and experiment showed good agreement [1] (measurements were made with the divertor Thomson system). However, the simplified fluid form for total parallel momentum was not conserved in the near-SOL [2], which implies kinetic effects are needed to properly predict the total pressure variation in the near-SOL. Taking care to include neutral friction and viscosity resulting from a Chew-Goldberger-Low (CGL) form of the pressure tensor (i.e. only the dominant diagonal terms) does not resolve the imbalance.

Here additional pressure tensor terms are added to the momentum equation, to determine their effect in the momentum balance in the scrape-off layer. This is similar to "pressure tensor unfolding"[3], but utilizing the full distribution function from XGCa to calculate the presumably higher order terms of the pressure tensor. We find that certain off-diagonal ion pressure tensor terms indeed have a non-negligible parallel variation, suggesting the need to include them in the full fluid parallel momentum balance equation.

Further simulations with higher ion collisionality are explored to study the effect of ion collisionality versus proximity to the separatrix on the momentum equation in the SOL.

[1] R.M. Churchill, J.M. Canik, C.S. Chang, R. Hager, A.W. Leonard, R. Maingi, R. Nazikian, D.P. Stotler, Nucl. Mater. Energy 12 (2017) 978–983.
[2] R.M. Churchill, J.M. Canik, C.S. Chang, R. Hager, A.W. Leonard, R. Maingi, R. Nazikian, D.P. Stotler, Nucl. Fusion 57 (2017) 46029.
[3] A.V. Chankin, P.C. Stangeby, Nucl. Fusion 46 (2006) 975–993.

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