Contrib. Plasma Phys. **44**, No. 1-3, 281 – 282 (2004) / **DOI** 10.1002/ctpp.200410042

Localized Gas Puffing Control of Edge Rotation and Electric Field

P. J. Catto*[1], **T. Fülöp**[2], and **P. Helander**[3]

[1] Plasma Science and Fusion Center, Massachusetts Institute of Technology
[2] Department of Electromagnetics, Chalmers University of Technology
[3] EURATOM/UKAEA Fusion Association, Culham Science Centre

Received 5 September 2003, accepted 9 Februar 2004
Published online 23 April 2004

Key words Tokamak, gas puffing, plasma rotation, neutrals.
PACS 52.55.Fa, 52.25.Ya

Neutrals at the edge of tokamaks can influence confinement by altering the radial electric field and toroidal plasma flow velocity through charge exchange and ionization interactions when the high diffusivity of the neutrals results in neutral viscosity dominating over ion neoclassical and turbulent viscosities [1-5]. We find that the flow and electric field are very sensitive to the poloidal location of the neutrals and the ion collisionality [6,7]. These predictions are consistent with differences observed on MAST between measured toroidal flows for inboard and outboard gas puffing, and may also explain observations indicating that inboard puffing allows easier H mode access [8]. In particular, we find that the inward directed radial electric field and counter-current directed outboard toroidal flow velocity in a collisional or Pfirsch-Schlüter edge plasma tend to be larger if the atoms are concentrated on the inboard side rather than on the outboard side [6,7] - consistent with the MAST results and suggesting that the flow shear introduced by the limited penetration of the neutrals and the radial variation of the ion temperature gradient suppresses edge turbulence and plays a role in forming the edge transport barrier. The ion temperature gradient terms enter because ion heat flow modifies the neutral viscosity via charge exchange.

The results are found to be relatively insensitive to neutral collisionality [4], which tends to cause up to order unity changes in amplitudes but not changes in direction. More importantly, the results are found to be sensitive to plasma collisionality [7] because of the important role played by ion temperature gradient terms - as in standard neoclassical theory. In the case of banana regime ions and collisional neutrals [7], inboard puffing reduces the counter-current rotation, while the radial electric field always remains inward. Consequently, if there is a narrow collisional layer separating the separatrix from the pedestal as in Alcator C-Mod, then this effect will further shear the flow. However, for banana regime ions the largest outboard toroidal flow is obtained for outboard puffing and is in the counter-current direction - suggesting that outboard puffing might be more effective in suppressing edge turbulence and generating an edge transport barrier in tokamaks which remain in the banana regime all the way to the separatrix (assuming no other source of flow shear). Finally, impurities affect the size of the flow and electric field; increasing the effect in the Pfirsch-Schlüter regime and decreasing it when the ions are in the banana regime [7]. These results suggest that flexible neutral fueling is desirable since it may allow some external control over the tokamak edge and overall performance.

In spite of any obvious source of momentum input, axisymmetric tokamak plasmas rotate toroidally. One mechanism causing the edge plasma to rotate can be summarized as follows. The magnetic field introduces a preferred direction. It breaks toroidal symmetry by requiring a Pfirsch-Schlüter heat flux with a preferred toroidal direction in order to satisfy the energy balance equation. The heat flow is due to the combined poloidal and toroidal magnetic field - there is no momentum input from magnetic fields. Because of charge exchange the neutral viscosity contains ion heat flow terms as well as the standard ion particle flow terms. These heat viscosity terms enable neutral atoms to transfer angular momentum between otherwise stationary flux surfaces. If the plasma did not interact with a wall there would be no net momentum transfer because of angular momentum. However, the plasma and neutrals do exchange momentum with the vessel wall, by ion losses and recycling, so

* Corresponding author: e-mail: catto@psfc.mit.edu

net momentum can be imparted to the plasma, which ”pushes off’” the wall and starts rotating in the opposite direction to the toroidal heat flux.

Acknowledgements This work was funded by EURATOM under association contracts with Sweden and UK, by the UK Engineering and Physical Sciences Research Council, and by the US Department of Energy.

References

[1] P.J. Catto, P. Helander, J.W. Connor, R.D. Hazeltine, ”Neutral Particle and Radiation Effects on Pfirsch-Schlüter Fluxes Near the Separatrix”, Phys. Plasmas **5**, 3961 (1998).
[2] T. Fülöp, P.J. Catto, P. Helander, ”Neutral Diffusion and Anomalous Effects on Ion Flow Shear”, Helander, Phys. Plasmas **5**, 3398 (1998).
[3] T. Fülöp, P.J. Catto, P. Helander, ”Neutral Diffusion and Anomalous Effects on Collisional Ion Flow Shear in Tokamaks”, Phys. Plasmas **5**, 3969 (1998).
[4] T. Fülöp, P.J. Catto, P. Helander, ”Effect of Neutral Atoms on Tokamak Edge Plasmas”, Phys. Plasmas **8**, 5214 (2001).
[5] A.N. Simakov, P.J. Catto, ”Effects of Poloidal Variation of Neutral Density on Pfirsch-Schlüter Transport Near Tokamak Edge”, Phys. Plasmas **10**, 398 (2003).
[6] T. Fülöp, P. Helander, P.J. Catto, ”Effect of Poloidal Density Variation of Neutral Atoms on the Tokamak Edge”, Phys. Rev. Lett. **89**, 225003 (2002).
[7] P. Helander, T. Fülöp, P.J. Catto, ”Controlling Edge Plasma Rotation Through Poloidally Localized Refueling”, to appear in Phys. Plasmas (Nov. 2003).
[8] ”H-mode Access Physics in MAST”, P.G. Carolan, A.R. Field, H. Meyer, et al, 19th IAEA Fusion Energy Conference, Lyon, France 14-19 October 2002, paper IAEA-CN-94/EX/C2-6, submitted to Nucl. Fusion.