### 2C30

# Plasma potential of an electrostatically driven plasma

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For a magnetized plasma, externally imposed electrostatic bias can induce both plasma current and plasma flow. The plasma current is driven by the parallel electric field along a magnetic field line and the magnitude of the current density is proportional to the Lundquist number. The parallel electric field, in a steady state plasma, is just the electrostatic potential drop along the magnetic field line. In a transient plasma, there is an additional inductive electric field piece corresponding to movement of the field line in the lab frame and relative slippage between the poloidal and toroidal flux linkage. The plasma flow in an electrostatically driven plasma is predominantly $\mathbf{E}\times\mathbf{B}/B^2$ with an ignorable correction inversely proportional to the Lundquist number. At steady state, the electric field is purely electrostatic, $\mathbf{E}=-\nabla\Phi$. The plasma potential $\Phi$ is central for the plasma current and flow drive by external voltage biasing.

Recent experiments have been devised to make use of both the current drive and flow drive capabilities of external voltage biasing. The Co-axial Helicity Injection (CHI) experiments on HIT-II and NSTX target electrostatic current drive as means for toroidal plasma startup and current sustainment. The Flowing Magnetized Plasma (FMP) experiment at LANL also employs a co-axial setup but emphasizes electrostatically driven plasma rotation. The sheared $\mathbf{B}\times\nabla\Phi/B^2$ plasma rotation simulates astrophysical accretion for studying magnetic rotational instability and dynamos.

The co-axial setup of voltage biasing insures that the external electrostatic drive conserves the toroidal magnetic flux inside the discharge chamber. A critical advantage is the ready accessibility of steady state operation. For CHI discharges, the plasma potential is directly responsible for parallel current drive, so force balance dictates the plasma potential. By that, we mean, for example, how far away the plasma potential is different from the vacuum potential. In fact, if the plasma inertia is ignored, the plasma potential is completely given by the Grad-Shafranov model and parallel resistive Ohm's law, hence the name Grad-Shafranov potential. The subtle physics of a small plasma inertia on modifying the plasma potential from the Grad-Shafranov potential will be clarified by both analytical calculation and numerical computation.

The ideal of the FMP experiment is to completely avoid plasma potential drop within a magnetic surface. Indeed, for a uniform vertical magnetic field, the vacuum potential ($\ln r$) and the associated Couette flow ($v_\varphi \propto r^{-1}$) are self-consistent solutions to the MHD equations. The experimental obstacle is the uncertainty regarding the accessibility of these solutions in a realistic discharge. In other words, the vacuum potential might not be an attractor for the plasma potential if one follows the plasma dynamics. We will present 2D and 3D numerical simulations that clarify the subtleties involved.

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