# Observation of peak neoclassical toroidal viscous force in the DIII-D tokamak*

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This work presents recent observations of a peak in the neoclassical toroidal viscous (NTV) force at low toroidal rotation and low radial electric field in the DIII-D tokamak. The peak was predicted by a simple theory model we developed which smoothly connects the $1/\nu$, $\sqrt{\nu}$, and superbanana-plateau asymptotic NTV regimes [1] relevant for low-collisionality ($\nu_i/\varepsilon \ll \omega_{bounce}$) tokamak plasmas. NTV originates from non-ambipolar radial particle drifts driven by non-axisymmetric magnetic fields that modify the ion parallel stress tensor.

Using the I-coils on DIII-D to apply a static non-resonant $n$=3 magnetic perturbation to a H-mode plasma, a rotation scan of the NTV torque was performed. Using neutral beam rotation feedback, the NTV torque was measured by comparing the beam power required to maintain a preprogrammed toroidal rotation value before and after the application of $n$=3 fields from the I-coils. The NTV peak occurs for toroidal rotation values where the radial electric field profile is near zero, as determined by radial force balance and is sensitive to the poloidal rotation profile. As a result, this experiment provides a test for the poloidal rotation predicted by neoclassical theory and will be further discussed.

A novel feature of NTV is that it damps the toroidal plasma rotation to a diamagnetic offset value observed to be $\Omega \sim 25$ krad/s in DIII-D H-mode plasmas [2], in much the same way as poloidal flow damping occurs in axisymmetric tokamaks. However, in the case of NTV, the field perturbations required to generate a toroidal torque can be quite small, of order $10^{-3}$ of the main toroidal guide field, and as such does not induce significant particle transport. The observation of a peak NTV torque for low toroidal rotation, causing a rotation spin-up to a diamagnetic offset in the tens of kilo-rads per second could prove beneficial for ITER startup, providing a necessary and inexpensive source of external toroidal momentum input and control when the plasma is most sensitive to disruption.

[1] K.C. Shaing, et al., Plasma Phys. Control. Fusion **51**, 035009 (2009) and references therein.
[2] A.M. Garofalo, et al., Phys. Plasmas **16**, 056119 (2009).

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