Calculating the Source Terms in the Momentum Transport Equation

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Overview
- Rotation Research and Motivation
- Overview of the Experimental Set-up
- Description of Calculations and Some Results
- Discussion and Acknowledgements

Introduction
Torsional plasma rotation has been seen to have a variety of beneficial effects on tokamak operation and physics including:
- suppressing instabilities such as the resistive wall mode, removing the necessity for external stabilizing coils.
- rotation shear breaking turbulent eddies, which creates transport barriers and improves confinement.
- rotation measurement allows calculating the radial electric field in a plasma, which is an important part of understanding H-mode physics.

The goal of this work is to compare plasma rotation measurements to models of momentum transport and identify the sources in several cases where no sources are observed.

Experimental Set-up
The key to identifying the velocity profile at C-Mod has been the High Resolution X-ray spectrometer (HiReX Sr) on C-Mod. This spectrometer is based on a spherical crystal design to achieve spatial, spectral, and temporal resolution of heliumlike and hydrogenlike argon lines from the C-Mod plasma. Argon is pulled into the C-Mod plasma for a majority of operation around 0.3 seconds into the discharge.

Description of Calculations and Results
The method used in this research to analyze momentum transport is the application of a modified model of momentum transport. In this model, written below in equation 1, momentum transport is allowed to vary based on a source, diffusive term, convective term, and residual stress. The convective term is proportional the velocity, and for simplicity the diffusive coefficient is constant in space and time. Therefore, this suggests that these plasmas are momentum diffusion dominated.

\[ P = \frac{\partial P}{\partial t} + \nabla \cdot (\alpha \mathbf{v} P - \nabla \cdot (\nabla P - P + \Pi)) \]

\[ P = \nabla \cdot (\alpha \mathbf{v} P) + \nabla \cdot (\nabla P - P + \Pi) \]

Despite the relatively flat profile, we observe source peaking at \( r/a \sim 0.6 \) (\( q \sim 1.57 \)). This suggests that the residual stress term may be localized in that location. In this situation, there appears a seeming relationship between pressure difference in gradient and the source term location.

SSEP Sweep
The last case to be shown is a plasma during the discharge of which the magnetic field is changed at the edge. In this discharge, the distance between the primary and secondary separatrix (SSEP) is changed, effectively switching the configuration from a lower null to an upper null. Since the only change that occurs is localized in the edge, any source should be localized to the edge of the plasma as well. There is a peaked velocity profile again, so in this case a \( v_c \) is calculated. Values of \( v_c \) used were 0.0, 10.0, and Porters et al.'s value of \( 2 \times 10^{-12} \text{m/s} \).

Discussion
- A wide variety of discharges can be studied with HiReX Sr and analyzed for momentum transport effects.
- L-H mode discharges appear to have a highly correlated non-diffusive momentum source with the difference in the pressure gradient.
- Rotation reversal discharges appear to have very little if any convective momentum transport and a large source term.
- Magnetic field configuration changes seem to be mostly diffusion dominated, with the source term changing in time.
- Future work includes looking at more discharges of each type, changing the convective transport term, using TRNSF for diffusion profile, comparing the discharges to GYRCS, and analyzing ICRF and Lower Hybrid source terms.

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Selected References

Figure 1. (a) Velocity profile; uncalibrated (b) Source profile for D = 1.0 m^2/s, v_c = 0.0 m/s (c) Average source profile after rotation inversion

Figure 2. (a) Velocity profile (b) Source profile for D = 1.0 m^2/s (c) Average change in pressure gradient from L-H mode transition

Figure 3. (a) Average change in pressure gradient from L-H mode transition (b) Average source profile for D = 1.0 m^2/s

Figure 4. Time trace of the SSEP evolution during this discharge

Figure 5. (a) Velocity profile (b) Source profile for D = 1.0 m^2/s (c) Average change in pressure gradient from L-H mode transition (d) Average source profile after rotation inversion

Figure 6. (a) Velocity profile (b) Source profile for D = 1.0 m^2/s (c) Average change in pressure gradient from L-H mode transition (d) Average source profile after rotation inversion

Figure 7. Change in pressure gradient across the plasma as a function of q/\( n \) for different values of D and \( v_c \).