Study of Intrinsic Rotation in Tokamak Plasmas

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Introduction

Controlling Nuclear fusion reactions in nuclear fusion is one of the most challenging tasks for humankind. The Tokamak is at present the most promising device for the magnetic confinement fusion as it has confined fusion plasmas for the longest time [1]. Rotation and rotational shear are very useful and advantageous for the plasma transport and to increase plasma stability. Currently, NBI is the most effective way to rotate the plasma. In future, fusion devices like ITER it will not be possible to rotate the plasma through NBI. Thus, the study of intrinsic rotation has utmost relevance. Pama, Barnes et al. [2, 3] proposed a gyrokinetic model to explain the intrinsic rotation. The new momentum transport model is being implemented in the code GS2. In this PhD project the modified GS2 code will be benchmarked with other codes as well as experimental data. The code will also be extended to include the study of impurity effects on rotation with second order correction.

Theory

Current theories for intrinsic rotation suggest that it can be self-generated from microturbulence [4]. The model proposed by P. I. Pama, M. Barnes et al. [2, 3] investigates the second order fluctuations of density n and temperature T profiles along with heating sources of plasma where the fluctuations are anisotropic with respect to equilibrium magnetic field. Expanding the distribution function

\[ f = f_0 + f_1 + f_2 \]

where \( f_0 = \delta f \) and \( f_1 = \delta^2 f \), by implying the condition \( \nu = 0 \) had a local gyrokinetic model is:

\[ \rho_* \ll \frac{\rho}{L} \frac{\omega}{V} \frac{\delta f}{f_0} \]

Where \( \rho \) is Larmor radius, \( L \) is characteristic length scale of machine, \( \omega \) is plasma frequency. Corresponding rotation in plasma from gyrokinetic model gives

\[ \delta \Omega_2 = F(\Omega_2, n, T, \delta \rho, \delta T, \Omega_2, \delta \Omega_2, \text{heating}(\rho, V)) \]

Where \( \Omega_2 \) is angular velocity in poloidal direction, \( V \) is the velocity vector, \( n \) is the density, \( T \) is the temperature, \( \delta \rho \) is the density gradient of the quantities, \( \delta T \) is the second derivative of quantities, \( \Omega_2 \) is the \( \Omega_2 \) gradient of the quantities.

Figure 1 shows the measurement of toroidal rotation using different heating sources

Preliminary results

Linear gyrokinetic simulations were performed to get familiar with the GS2 code. Only first order gyrokinetic model is used to obtain preliminary result before understanding the second order gyrokinetic. In figure 2 for DIII-D discharge using a simplified magnetic equilibrium known as Cyclone base case [6]. This is a high confinement shot (H1490) at time \( t = 400 \) ms, \( m = 0.5a \),

![Figure 2](image)

![Figure 3](image)

Figure 2: a) Growth rate and frequency of ITG of DIII-D shot H1490 (b) Flux surface of DIII-D shot H1490 (x-axis is R in meters and y-axis is 2 in meters). It is a poloidal cross-section of tokamak.

Figure 3: a) Growth rate and frequency of ITG of JET shot #74575 (b) Flux surface of JET shot #74575 (x-axis is R in meters and y-axis is 2 in meters). It is a poloidal cross-section of tokamak.

Conclusions and Future work

Linear gyrokinetic simulations were performed for a DIII-D shot 61499, the cyclone base case (CBC) and a JET shot #74575 using the experimental equilibrium. ITG modes were obtained for both the DIII-D CBC and the JET shot. For the JET shot the observation of ITG together with counter-rotation in the plasma-core is consistent with observations of intrinsic rotation in the tokamak Alcator-CMOD [7].

The JET shot will require further investigation to determine if Trapped Electron mode (TEM) exists. Another approach to obtain the TEM is by using initial value solver instead of eigenvalue solver. Further analysis of other parameters like collisionality, impurity type and impurity density will be performed in future.

References


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