IAEA FEC 2014

Contribution ID: **523** Type: **Poster**

Plasma Rotation Alteration by Non-Axisymmetric Magnetic Fields, Resistive MHD Stability Analysis, and High Normalized Beta Plasmas Exceeding the Ideal Stability Limit in KSTAR

Friday 17 October 2014 14:00 (4h 45m)

H-mode plasma operation of KSTAR has been expanded to reach the ideal MHD no-wall beta limit. The closest approach to this limit has achieved high normalized beta, beta_N, up to 2.8 while reducing plasma internal inductance, l_i, to near 0.7 exceeding the computed n = 1 ideal no-wall limit. The ratio of beta_N/l_i, has reached 4 and the maximum plasma stored energy has exceeded 0.5 MJ. As a method to access the ITER-relevant low plasma rotation regime, non-resonant alteration of the rotation profile by non-axisymmetric magnetic fields has been demonstrated, enabling a study of the underlying neoclassical toroidal viscosity (NTV) physics. Non-axisymmetric field spectra were applied using in-vessel control coils (IVCCs) with varied n = 2 field spectra (by different combinations of upper/lower and middle IVCCs), electron cyclotron heating, and supersonic molecular beam injection to alter the plasma rotation profile in high beta H-mode plasmas and analyze their distinct effects on the rotation. The rotation profile was significantly altered with rotation reduced by more than 60% using the full range of techniques used as measured by several diagnostics without tearing activity or mode locking. To investigate the physical aspects of the measured rotation braking by NTV, changes in the steady-state rotation profiles are analytically examined by using the toroidal momentum balance equation in order to isolate the effect of the NTV. The NTV scaling with delta B^2 shows good agreement with the measured profile change. The NTV coefficient scales as T_i^2.27, in general agreement with the low collisionality '1/nu'regime scaling of NTV theory. Determination of the classical tearing stability index, Delta', is a crucial foundation for analysis at high beta. The 2/1 tearing stability in KSTAR is first quantified by using Delta' calculated from the PEST-3 code. The stability calculation is examined for a 2/1 mode residing at low beta where pressure driven effects are expected to be small. The mode evolution is well described by the calculated Delta'. The robustness of the calculations is tested by varying the q_0 constraint which results in a modest change in Delta', however, the systematic change in sign of Delta' remains consistent with the measured mode behavior. The stability calculations using the M3D-C1 code show qualitative agreement with Delta' from PEST-3.

Country or International Organisation

USA

Paper Number

EX/P8-5

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Session Classification: Poster 8