Contribution ID: **485** Type: **Poster**

Energy Confinement and Performance of Pure Helium Plasmas and Helium Seeded Deuterium Plasmas

Friday, October 26, 2018 2:00 PM (20 minutes)

The presence of fusion-produced helium is fundamentally connected to the performance of a fusion reactor. Not only will He ash dilute the fusion fuel if not removed promptly, but the presence of He in a D plasma is reported to negatively affect the plasma confinement [1]. Furthermore, He plasmas are a choice for the ITER non-nuclear phase, but the energy confinement in such plasmas is consistently observed to be ˜30% lower than in D plasmas [2, 3].

The negative impact on the performance observed with reactor relevant concentrations of He in D plasmas is demonstrated and compared in baseline scenario plasmas in JET and in plasmas with and without N-seeding in ASDEX Upgrade (AUG). In both devices, a significant reduction of the plasma stored energy (and normalised confinement factor H98(y,2)) is observed with increasing He concentration. Helium impacts the edge and core plasma profiles in a phenomenologically similar way in the two machines, and also affects the ELM behavior, and the produced neutrons. However, both the core and edge contribute to the loss of stored energy at AUG, while the core alone is responsible for the loss of stored energy at JET. In both JET and AUG, after applied short He puffs, the confinement is observed to recover at the same rate as the He concentration decays.

Additionally, the confinement of pure He plasmas at AUG is studied, demonstrating plasma conditions where confinement in He is the same as in D plasmas. Pairs of L- and H-mode plasmas in He and D have been produced, in which a large variation of the electron to ion heating fraction is obtained using the ECRH and the NBI systems. Two regimes are identified. With strong ECRH and low electron density, the confinement in He is equivalent to that in D. With strong NBI heating, there is a significant degradation of the confinement in He (˜70% of the corresponding D plasma). These observations are theoretically explained. In the core, the stronger impact of zonal flows in ITG turbulence as compared to TEM turbulence breaks the gyro-Bohm scaling in the strong NBI case. At the edge, thermal coupling and the destabilization of ETG modes in He prevent the increase of the ion and electron temperatures.

[1] R. Neu et al, Proc. 35th EPS Conf. (2008),
[2] F. Ryter et al, Nucl. Fusion 49, 62003 (2009),
[3] D.C. McDonald et al, Plasma Phys. Control. Fusion 46, 519 (2004)

Country or International Organization

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Paper Number

EX/P8-1

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Session Classification: P8 Posters