Alfvén eigenmode analysis of strong electron heated pulses of JET DTE2 plasmas using MEGA

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I - Introduction

The DTE2 experimental campaign conducted at JET tokamak was an excellent opportunity to investigate crucial aspects of D-T plasmas beyond fusion energy maximization [1]. In DTE2 it was possible to probe characteristics vital for future fusion reactors namely plasma regimes with electron-dominated heating and low input torque. When adding ~4MW ion cyclotron frequency (ICRF) heating to pre-existent ~4MW of Neutral Beam Injection (NBI), some experimental evidence suggests that a D-T plasma with $\sim 50\%D - 50\%T$ can showcase a significant increase in energy confinement despite the coexistence of deleterious Alfvén wave and magnetic reconnection instabilities. Such increase in confinement is absent in D-only plasmas even if the phenomenology of interplay between TAEs and low frequency neoclassical tearing modes (NTMs) triggered by sawteeth appears similar. In addition, despite operating in L-mode, there is strong evidence in the D-T plasmas of a pedestal in edge electron temperature and slight density peaking in contrast to typical D plasmas at similar power [2]. In this work, we analyse the MHD phenomenology characterising the DT pulse 99896 to illustrate the complex interplay between low and high frequency MHD modes in the operational scenario emphasising on the energetic particle driven TAEs+fishbones and on the NTMs. The linear and non-linear analysis of the dominant n=4,5 TAEs observed is addressed using the hybrid MHD kinetic code MEGA [3].

II – Discharge characteristic and experimental results

The DT pulse 99896 is an L-mode discharge with edge Te pedestal and low edge fluctuations (ELMs absent except at highest power). Dipole phasing 4.5MW of ICRH (1-2% H minority) and both D-beams (3.7MW) and T-beams (3.1MW) were used consecutively in the discharge (transition at t=48.9s), as shown in Figure 1. As ICRH power couples to the plasma (t=47s), core electron temperature increases by a factor ~2.6, toroidal mode number n=1 fishbones emerge and the first sawtooth (ST) crash triggers n=3 and n=5 NTMs (see Figure 2). Using MHD spectroscopy and D-ion toroidal rotation inferred from carbon charge exchange, phase inversion of the ECE signal with Te fluctuations from the n=3 NTM indicate that at t~48.57s the plasma rotates with $f_\phi \sim 4.2kHz$ in the vicinity of the q~4/3 flux surface where the n=3 NTM is resonant (R~3.4m at $Z=Z_{mag}$). The plasma rotation frequency slightly inward i.e. where n=3,4,5,6 TAEs are resonant given the q(s) safety factor profile, is of the order $f_\phi \sim 4.3 - 4.7kHz$. The safety profile, as inferred from TRANSP at t=48.57s, is slightly hollow with q_{min} at s~0.18 and a double q=1 surface (s~0.06 and s~0.33) with the radial squared root normalised

[a] see the author list of "Overview of T and D-T results in JET with ITER-like wall" by CF Maggi et al. to be published in Nuclear Fusion Special Issue: Overview and Summary Papers from the 29th Fusion Energy Conference (London, UK, 16-21 October 2023)

[b] See the author list of "Progress on an exhaust solution for a reactor using EUROfusion multi-machines capabilities" by E. Joffrin et al. to be published in Nuclear Fusion Special Issue: Overview and Summary Papers from the 29th Fusion Energy Conference