8th AAPPS-DPP, November 3-8, 2024, Malacca, Malaysia

High-beta NTM in JET experiments in preparation of JT-60SA operations

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The MHD activity of high-beta plasmas has been analyzed on a series of pulses carried out at JET in 2023 with dimensionless parameter values (normalized beta β_N, collisionality ν^*, normalized Larmor radius ρ^*) relatively close to the JT-60SA scenarios hybrid and advanced [1]. These experiments were intended to identify an optimal set of parameters for pulses with mild MHD activity, and directly inform the design of pulses applicable to JT-60SA scenarios. Deuterium plasmas were performed in a variant of the JET hybrid scenario [2] at toroidal magnetic field $B_T = 1.7, 2.0, 2.4$ T, moderate plasma current $I_p = 1.4$ MA ($q_{95} = 3.5$-5.0), elongation $k = 1.6$, and high triangularity $\delta \approx 0.4$. Two scans were executed for each B_T value, which helped explore MHD stability boundary: **i)** an NBI power scan ($P_{NBI} = 16$-25 MW), affecting β_N, as already reported at JET for lower NBI power values [3]; **ii)** an NBI start time scan, affecting the central safety factor q_0, which is a key ingredient for MHD stability of the high beta phase. As general results of the experiments, good confinement properties were obtained, with mild MHD activity and relatively high β_N values, ranging from 2.5 at 2.4 T and 3.5 at 1.7 T.

In this contribution, the analysis of Neoclassical Tearing Modes (NTM) with different poloidal (m) and toroidal (n) mode numbers is reported, with a focus on 3/2 and 2/1 NTM, both regarding the destabilization mechanisms and the effect on confinement. Results showed agreement with previous observations on other devices, such as TFTR [4] and DIII-D [5], and on JET with C-wall [6-7], for pulses not affected by high-Z impurity accumulation. Pulses with $q_0 \approx 1$ at NBI swith-on showed $q = 1$ MHD activity during the heated phase, either in form of fishbones or sporadic sawteeth, both capable of triggering 3/2 modes, without a strong effect on confinement, and a decrease in the $q = 1$ MHD activity is observed after the 3/2 destabilization, suggesting the possibility of a "flux-pumping mechanism" as observed on DIII-D [5]. The destabilization of a 2/1 NTM is sometimes observed in the second half of the pulse, probably associated with the plasma current diffusion [9]. A β_N decrease and a core impurity accumulation is observed in this case, sometimes leading to a plasma disruption. Pulses with $q_0 \approx 1.2$ during the main heating phase were obtained anticipating the NBI switch-on. These pulses also showed 3/2 NTM at high β_N values, with a destabilization threshold roughly scaling as $1/B_T$, suggesting the poloidal beta as the relevant parameter for the stability boundaries, even if a possible dependence on the location of the rational surfaces for different q_{95} values must be considered. Results from interpretative TRANSP simulations and MHD linear stability analysis will be presented, detailing investigation of the causes of these high-beta NTM in sawtooth free plasmas. A possible role of already existing ideal kink-like modes, through a kink-to-tearing conversion, will also be investigated [10].

Two pulses at $B_T = 2.4$ T were performed in the last Deuterium Tritium experimental campaign at JET, with similar NBI power and plasma density, showing a different MHD behavior for the higher power pulse, likely due to the isotope mass effect on q-profile shape [11]. Two new reference pulses were then performed in the following Deuterium campaigns decreasing the plasma density during the I_p ramp-up phase to match the electron temperature peaking [12], used as a proxy for q_0 value, so recovering the same MHD behavior of Deuterium Tritium pulses and suggesting the possibility of a further scenario improvement by means of a density optimization.

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