Destabilization of Micro-Tearing Modes on MAST-U

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Edge turbulence significantly contributes to anomalous heat and particle transport in fusion plasmas. Micro-tearing modes (MTMs), destabilized by electron-temperature gradient, may account for a substantial portion of this anomalous heat transport at the plasma edge [1]. These modes impose a limit on the achievable electron temperature gradient in the pedestal region, thereby constraining confinement and overall plasma performance. MTMs have been observed in the pedestal regions of conventional aspect ratio tokamaks, such as JET [2] and DIII-D [3] but have not yet been detected in spherical tokamaks.

Theoretical and experimental studies indicate that MTMs become destabilized when a rational magnetic surface aligns with the peak of the drift frequency profile, ω^* [4]. Additionally, high plasma beta and collisionality influence their growth rate [5]. Under these conditions, MTMs can be investigated by analyzing their magnetic signatures using Mirnov coils, and by evaluating their characteristics, such as the dependence of their growth rate on electron temperature gradient and the ratio of Δn/n to ΔB/B [6].

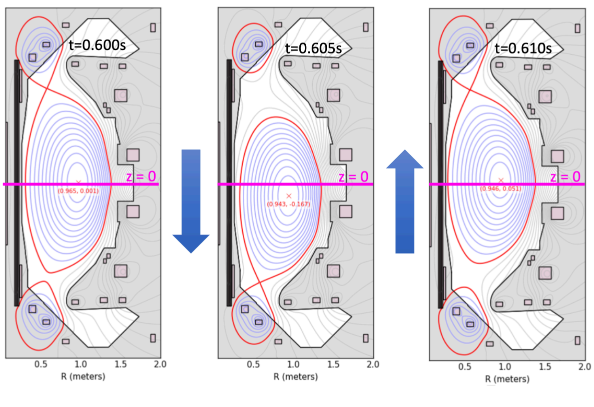

Figure 1: Example of rapid vertical displacement

Experiments were dedicated to investigating MTMs on the MAST-U spherical tokamak in the latest experimental campaign. Rapid vertical kicks (see Fig. 1) were introduced to the plasma in both upward and downward directions. Vertical kicks could destabilize MTMs by increasing the edge current density, modifying the q profile, and shifting the position of the rational surfaces with respect to peak of the ω^* profile. The kicks displaced the plasma 10 cm upwards and 24cm downwards while compressing it and triggering edge localized modes (ELMs). q_{95} changed from -6.7 to -4.6 during the kick. Significant density pump-out was observed during the kicks, accompanied by decreases in normalized beta (β_N), plasma volume, and stored energy (W_{MHD}), while the plasma current (I_p) remained unaffected.

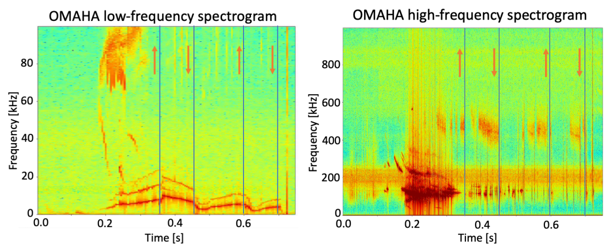

Figure 2: Mirnov-coil spectrogram during vertical kicks

The analysis of magnetic fluctuations (see Fig. 2) did not indicate the presence of destabilized micro-tearing modes. The modes were also absent in the density fluctuations analyzed with beam emission spectroscopy (BES). To understand the underlying reasons for these observations, gyro-kinetic simulations were conducted.

The long-lived mode (LLM) visible in Fig. 2 (left) between 5-20 kHz, characteristic of MAST-U plasmas, is chirped by the applied kicks. After the fourth kick, the LLM becomes locked, leading to plasma disruption. No additional low-frequency modes were destabilized by the kicks. The low-frequency LLM was also evident in the density fluctuation spectrum measured by BES. A high-frequency (HF) n = 0 mode appeared between 400-600 kHz in the magnetic spectrum and stabilized after the kicks (Fig. 2, right). This HF mode was not detected in the density fluctuation spectrum. Given that MTMs represent n > 0 modes characterized by both magnetic and density fluctuations, the sensitivity of the fluctuation measurements and the precise underlying mechanisms driving these fluctuations were also investigated.

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