MHD Activities and Plasma Confinement in Hot Ion Discharges with High Fast Ion Fractions in KSTAR

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Recently, a hot-ion scenario characterized by a high fraction of fast ions, termed Fast Ion Regulated Enhancement (FIRE) mode, has been developed in KSTAR [1,2]. The FIRE mode has been sustained for several tens of seconds, achieving plasma performance comparable to the H-mode scenario ($\beta_N \approx 2$ and $H_{89} \approx 2.4$). Power balance analysis and gyrokinetic simulations indicate that the enhanced confinement in these discharges is primarily due to the stabilizing effects of fast ions on turbulence [1,3,4].

However, various magnetohydrodynamic (MHD) activities, some seemingly induced by fast ions, have been observed in FIRE mode, limiting plasma performance. This study presents experimental observations of these MHD activities and their impact on plasma confinement. One commonly observed MHD activity exhibits a frequency near the BAE/KBM branch and is occasionally associated with neutron deficits accompanied by strong frequency chirping. Another MHD activity, with a frequency near the BAAE branch (lower than the BAE/KBM branch), causes significant confinement degradation. These detrimental MHD activities can be mitigated or avoided by optimizing NBI power and plasma density. During the 2024 KSTAR campaign, experiments aimed at improving FIRE mode discharges through higher plasma density are planned. This study also discusses the updates from recent KSTAR FIRE mode experiments and transport modeling that considers the effects of fast ions for successful predictive simulations.

References

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