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Current-driven kink instability of magnetized plasma column surrounded by background plasma

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One of the well-known and studied magnetohydrodynamics (MHD) instabilities is a current-driven kink instability. The kink instability in current-carrying plasma column has played an important role for astrophysical problems, fusion research and basic plasma physics. In the Sun's corona, the kink instability of the current-carrying plasma columns(a high-density filament called a prominence) has been considered as a main cause of the flare[1,2]. In fusion research, a peaked current profile makes the tokamak plasma unstable to a helical MHD kink mode, giving sawtooth relaxation oscillations[3,4]. Also, an electrostatic (DC) helicity injection, a non-inductive current driving and startup method for Spherical Torus (STs), has been utilized the current-carrying plasma column and its dynamics[5,6]. The ideal MHD stability of current-carrying plasma column for an infinitely long column is determined by the Kruskal-Shafranov limit[7,8]. Also, system geometry and boundary condition strongly affect the kink mode structure and stability condition[9,10].

However, despite both most of current-carrying plasma column have coexisted with background plasma and the surrounding background plasma highly affect the kink instability properties, the effects of background plasma on kink instability of current-carrying plasma column have yet to be investigated. So, the goal of this work is to study the effects of background plasma on kink instability and its kink properties.

To generate magnetized current-carrying plasma column with the background plasma, plasma guns installed in Versatile Experiment Spherical Torus (VEST), the fist ST in South Korea, are used[5,11]. By adjusting both source plasma in plasma gun and voltage applied between the plasma gun and chamber, the background plasma and current-carrying plasma column can be discharged simultaneously. When source plasma in the plasma gun is discharged, some of source plasma is diffused out by internal pressure in the plasma gun, thereby giving background plasma.

The magnetic diagnostics measurements are presented for the kink instability in a plasma column surrounded by background plasma. These are accurately reproduced by a simple rotating model and a phenomenological kink theory[10] which considers both boundary conditions and axial plasma flow. Its stability and properties such as mode structure and coherent rotating frequency has been studied. The background plasma act like an ideal (highly conducting) wall, thereby stabilizing external kink instability to internal kink instability. Interestingly, however, the stabilized current-carrying plasma column by background plasma has external kink properties such as kink mode structure and coherent rotating frequency predicted by a phenomenological model.

References

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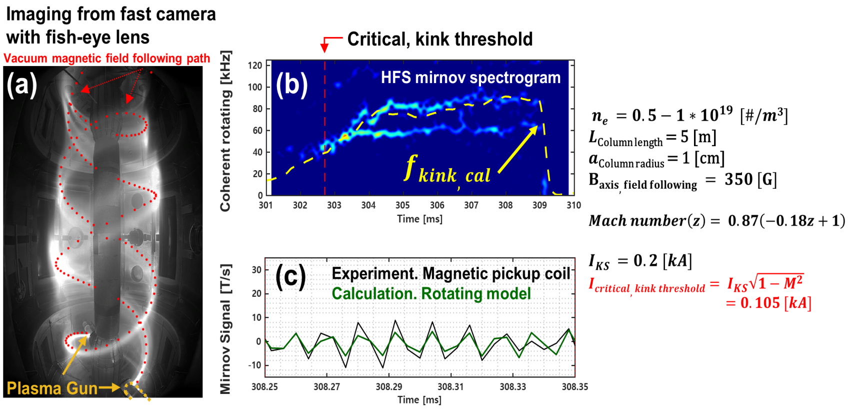

Figure 1. Discharged current-carrying plasma columns following helical vacuum magnetic field of VEST (a). Note that imaging from fast camera with fish-eye lens. The magnetic signal measurement and reproduced results using both rotating model and phenomenological theory are shown in (b), (c). The rotating frequency well matched under background plasma condition (b) and rotating model give cross-correlation of 0.8 (c). For this calculation, as neutral gas injected during discharge at upstream(near the gun), linearly decreasing mach number are assumed.