Contribution ID: **67**

Type: **Poster**

Effects of equilibrium pressure on plasma response to RMPs in a spherical tokamak

This study presents a comprehensive analysis of the equilibrium pressure on the plasma response to resonant magnetic perturbations (RMPs) in the spherical tokamak (ST) MAST-U, employing both single-fluid and MHD-kinetic hybrid models (implemented via the MARS-F/K codes). As a key finding, the study identifies two different pressure-driven eigenmodes, exhibiting Sturmian property, that affect the Troyon no-wall limits for the onset of the $n = 1$ and $n = 2$ (n is the toroidal mode number) ideal external kink instabilities as well as the corresponding plasma response to the applied RMP. With increasing equilibrium pressure, the plasma response to RMPs is significantly enhanced in the ST plasma, particularly in the high-pressure regime where kinetic effects strongly stabilize the external kink instability. The Troyon no-wall limit divides the plasma response into two regions: well below the limit, the response amplitudes and trends (versus pressure) are similar between the fluid and kinetic models; as the equilibrium pressure approaches the Troyon limit, the kinetic model predicts significant amplification of the RMP field, up to 30 times for cases considered. A relatively weak dependence of the optimal coil phasing on the equilibrium pressure is computed in this ST plasma, similar to the trend obtained for the conventional aspect ratio devices. These findings underscore the importance of incorporating kinetic effects in accurate prediction of the plasma response to RMPs in high-pressure ST tokamak plasmas and provide a theoretical basis for optimizing RMP-based control of the edge-localized modes in future ST devices.

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Session Classification: Poster Session #2