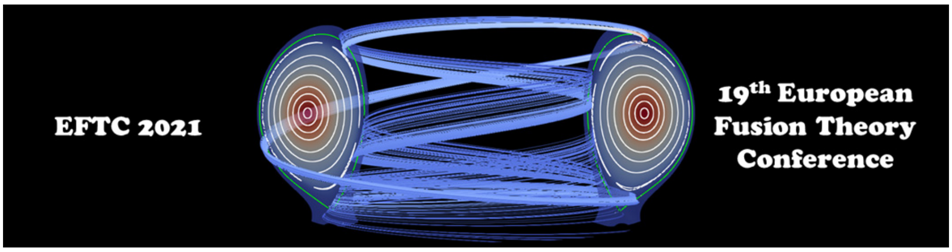

Contribution ID: **36** Type: **Oral**

Impact of divertor X-points on axisymmetric modes in tokamaks

Wednesday 13 October 2021 14:30 (20 minutes)

The ideal-MHD theory of axisymmetric modes with toroidal mode number n = 0 in tokamak plasmas is developed. These modes are resonant at the magnetic X-points of the tokamak divertor separatrix. Consequently, current sheets form along the separatrix, which profoundly affect the stability of vertical plasma displacements. In particular, current sheets at the magnetic separatrix lead to stabilization of n = 0 modes, at least on the ideal-MHD time scale, adding an essential ingredient to the mechanism of passive feedback stabilization. The theory discussed here presents analogies with the physics of current sheet formation from the evolution of internal kink modes and the magnetic island coalescence problem. In these works, the ideal-MHD constraint causes magnetic flux to pile up near the X-points, leading to perturbed localized currents and a stabilizing effect in the ideal-MHD limit. For the island coalescence problem, it was found that a chain of magnetic islands becomes ideal-MHD unstable when the island width exceeds a critical threshold. In any case, flux pile-up prevents any further nonlinear evolution for unstable internal kinks and island coalescence unless the ideal-MHD constraint is relaxed, e.g., by resistivity. In our problem, vertical displacements are linearly stable in the ideal-MHD limit when the mode resonance at the equilibrium X-points of the divertor separatrix is appropriately taken into account. We remark that the resonant behavior of n=0 modes at divertor X-points is an ideal-MHD phenomenon. Therefore, it is reasonable that it must be treated first according to ideal-MHD. Future work will consider extended-MHD effects. We have found that, when the plasma density extends to the magnetic separatrix and n = 0 perturbations resonate at the magnetic X-points, vertical displacements are stable, at least on ideal-MHD time scales, without any need for passive stabilization elements. The stabilization mechanism is a direct consequence of the ideal-MHD flux-freezing constraint on the X-points, generating current sheets localized along the magnetic separatrix, exerting a force capable of pushing back the plasma in its vertical motion. This also suggests that plasma electrical resistivity in a thin boundary layer along the magnetic separatrix, in addition to wall resistivity, may have a profound impact on the stability of n = 0 vertical displacements.

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Session Classification: ORAL SESSION

Track Classification: 2. Macro-instabilities, operational limits and disruptions