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Negative Triangularity Tokamak: Stability Limits and Perspectives as Fusion Energy System

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Fusion research has to solve the power handling toward fusion demonstration power reactor (DEMO). A tokamak plasma with strongly negative triangularity may offer such an opportunity as an innovative concept. The present paper discusses the edge stability, beta limits and power handling issues for the negative triangularity tokamaks. The edge MHD stability is the most crucial item for power handling in tokamak. The key design philosophy is to achieve a "soft edge beta limit" instead of achieving the highest possible beta for the steady state operation with a high bootstrap current fraction. This may lead to a fundamental change to the direction of advanced tokamak research. That is why negative triangularity tokamak plasmas are subject to an increased interest both in existing experiments and in studies of core physics as well as power handling relevant to DEMO.

For the case of negative triangularity, the 2nd stability access is closed for ballooning modes. The destabilization of a whole range of fixed boundary medium- and low-n modes takes place for pedestal heights just above the values for which the Mercier criterion for localized modes is violated, implying possible changes in the ELM characteristics. While negative triangularity plasma has some favorable MHD property to ELMs, the beta limit is relatively low. Negative triangularity tokamak configurations with optimized pressure gradient profiles can be stable for normalized beta ˜ 3 at moderate elongation k = 1.5 and internal inductance value 0.9, even in the absence of the magnetic well.

Apart from the ELM mitigation, negative triangularity tokamaks feature other possibilities for power handling such as naturally increased separatrix wetted area and more flexible divertor configuration using PF coils inside the TF coil made of NbTi superconductor in the low field region. Negative triangularity experiments in TCV show a reduction in electron heat transport by a factor two compared with D-shaped configuration, which is partly explained by nonlinear gyrokinetic simulations. This configuration also allows the inboard ECRF launching to have higher density limit for the ECRF propagation and better pumping accessibility due to larger conductance. The SOL width may also be modified especially in the case of double null configuration with almost vertical magnetic surfaces at the LFS.

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