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Structural analyses of the in-vessel ELM control coils of the TCABR tokamak

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An upgrade of the TCABR tokamak ($R_0 = 0.62$ m, $a = 0.18$ m, $I_p \leq 120$ kA e $B_0 \leq 1.1$ T) is being carried out to allow for studies of the impact of resonant magnetic perturbation (RMP) fields on plasma instabilities known as edge localized modes (ELMs). ELMs may impinge heat fluxes on the surface of plasma-facing components that are typically well above the values supported by the existing advanced materials. It has been shown that RMP fields of relatively small amplitude may reduce heat fluxes caused by ELMs to values below the allowable thresholds supported by plasma facing components. To study the impact of RMP fields on ELMs in TCABR plasmas, an innovative set of in-vessel RMP coils are being designed. In this work, the mechanical design of those coils is presented. For the coils to work properly, a set of engineering requirements must be met. Firstly, magnetohydrodynamic (MHD) simulations using the non-linear two-fluid resistive MHD code M3D-C^1 show that, to meet the physical requirements, the coils must withstand currents as high as 60 kA-turn. Also, the coils will have to operate with both direct and alternating currents, at frequencies up to 10 kHz. Due to their relatively high self-inductances, the coils will have to withstand peak voltages of up to 4 kV. Since these coils will be subject to a strong magnetic field (about 2.25 T), they will also experience strong magnetic forces (as high as 10 kN). Finally, since the coils will be installed inside the vacuum vessel, the materials and processes employed in their fabrication must be compatible with high vacuum (p $\geq 1 \times 10^{-8}$ mbar) and withstand temperatures of about 200°C during wall conditioning. All these requirements make the design and construction of this set of coils a significant challenge. Due to the complexity of the system, the design of the coils is being carried out with a transdisciplinary approach and support from multi-physics simulations in finite-element Ansys software. The maximum equivalent von-Mises stresses obtained for the proposed mechanical design satisfies both ASME and ITER criteria.

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