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Sensitivity of First Wall thermal-mechanical performance on cooling channel geometry and thermal conductivity

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The First Wall (FW) of DEMO or following fusion power reactors will be exposed to high heat fluxes by thermal radiation and energetic particles from the plasma. During steady state, values of over 1 MW/m^2 are expected for the EU DEMO concept. The function of the FW therefore relies on (1) good thermal conduction from the plasma facing surface through the channel material, and (2) good heat transfer from the channel wall surface into the coolant medium flow. Those aspects influence the shell-average operation temperature of the structural material - determining the materials mechanical strength - and also the temperature spreads within the component - causing thermally induced secondary stresses.

For given boundary conditions, FW designs can be thermal-mechanically optimized. In practice, deviations between the optimum design point versus the device under service have to be accepted due to manufacturing tolerances and variable coolant conditions for variably sized channels. This paper assesses sensitivities of the temperature and stress fields by a parameter study performed by finite element analyses, considering also feedback of the channel geometry to the relative flow ratio through individual channels, using validated correlations for helium thermal-hydraulics.

Further consideration is given to the materials thermal conductivity, which can vary with alloy composition and material history. Thermal conductivities of FW candidate reduced activating ferritic/martensitic steels are reviewed, and own measurements are reported. The possible tolerance in the thermal conductivity due to tolerances in the alloy composition is assessed by application of a neural network trained specifically to the named family of steels.

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