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Thermal hydraulic modeling and analysis of ITER tungsten divertor mono block

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The divertor is a fundamental component of fusion power plants, being primarily responsible for power exhaust and impurity removal via guided plasma exhaust. Due to its position and functions, the divertor has to sustain very high heat flux arising from the plasma (up to 20 MW/m2), while experiencing an intense nuclear deposited power, which could jeopardize its structure and limit its lifetime. Therefore, attention has to be paid to the thermal-hydraulic design of its cooling system. In this work a mathematical model has been developed/updated to investigate the steady state and transient thermal-hydraulic performance of ITER tungsten divertor mono block. The model predicts the thermal response of the divertor structural materials and coolant channel. The selected heat transfer correlations cover all operating conditions of ITER under both normal and off-normal situations. The model also accounts for the melting, vaporization, and solidification of the armour material. The model divides the coolant channels into a specified axial regions and the divertor plate into a specified radial zones, then a two-dimensional heat conduction calculation is created to predict the temperature distribution for both steady and transient states. The model is verified against a previous calculation in the literature for DEMO divertor at an incident surface heat flux of 10 MW/m2. The model is then used to predict the steady state thermal behaviour of the divertor under incident surface heat fluxes ranges from 2 to 20 MW/m2 for a bare cooling tube and a cooling tube with swirl-tap insertion. The model calculates maximum tube surface heat flux and the minimum critical heat flux ratio for all cases as well. The model is also used to simulate the divertor materials response subjected to high heat flux during a vertical displacement event (VDE) where 60 MJ/m2 plasma energy is deposited over 500 ms.

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