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Study on the Thermal Performance of ITER Tungsten Divertor Monoblock Using Nanofluid for Cooling Enhancement

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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. It is necessary to take effective cooling methods from the divertor which can sustain very high heat fluxes. In a previous work, the author developed a mathematical model to investigate the steady state and transient thermal–hydraulic performance of ITER tungsten divertor monoblock. The model could predict the thermal response of the divertor structural materials for bare cooling tube and a cooling tube with swirl-tape insertion. Nanofluids have gained extensive attention due to their role in improving the efficiency of thermal systems. Azmi et al. report a further enhancement in heat transfer coefficients in combination with structural modifications of flow systems namely, the addition of tape inserts. In this work a mathematical model has been developed/updated to investigate the thermal performance of the ITER tungsten divertor monoblock using new heat transfer enhancement technique. In order to enhance the heat transfer process, a water based TiO2 nanofluid at 3% concentrations is used to cool the divertor. 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 nanofuild cooled tube with swirl-tape insertion as well as water cooled bare and swirl-tape tubes. The operating conditions are: inlet temperature: 150℃, pressure: 5 MPa and coolant velocity: 16 m/s. Calculations are performed for incident surface heat flux of 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 MW/m2. Fig. 1 shows the variation of the predicted maximum tube-surface temperature values versus the incident heat flux for a divertor of bare tube, swirl-tape tube and swirl-tape tube cooled by nanofluid. It shows that, for bare tube divertor, the-maximum tube wall surface temperature exceeds the ONB temperature for incident heat fluxes greater than 10 MW/m2and so subcooled boiling is predicted at the top surface of the tube, and for swirl-tape tube divertor, subcooled boiling is predicted at the top surface of the tube for incident heat fluxes greater than 18 MW/m2. On the other hand, the combined effect of swirl-tape insertion and nanofluid shows a maximum tube-surface temperature lower than the ONB temperature by a considerable margin even at an incident surface heat flux of 20 MW/m2.

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Fig. 1. Maximum tube-surface temperature.

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