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Computational Fluid Dynamic analysis of Screw tube relevant for fusion applications

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Determination of the likely heat loads which may be expected on the First Wall (FW) of the projected European fusion reactor DEMO is still underway. This uncertainty notwithstanding, the engineering design of the heat sink components must proceed, hence the scientific community is using the so called bottom-up approach to determine the maximum heat flux that the component could sustain given currently existing material limitations and forecast operating conditions. The European DEMO most likely use a Reduced Activation Ferritic Martensitic steel called Eurofer 97 as the heat sink material for the FW. In terms of operating conditions one concept uses water as a coolant at PWR conditions i.e. 15.5 MPa and 285 ℃. The main challenge is that if the heat loads on the DEMO FW are extrapolated from ITER, they could be very high. Conversely the upper temperature limit of Eurofer is 550 ℃. Given also its low thermal conductivity ˜30 W/m K (far lower than that of CuCrZr which is the heat sink material in ITER) and an operational coolant wall temperature of 285 ℃, the design of the heat-sink is difficult.

The current work attempts to study the heat absorption capability of the heat sink using a turbulence/critical heat flux enhancer inside the cooling channel known as a screw tube, by using Computational Fluid Dynamics (CFD). A screw tube is a cooling tube with a helical triangular fin on its inner surface. The nut-like inner surface works as a combination of enhanced heat transfer area and turbulence promoter. In the literature, several experiments have been performed to determine the heat evacuation capability improvement from screw tubes but none has studied the fluid dynamics and heat transfer in detail. In this work, a commercial CFD code STAR-CCM+ is used to study the flow physics, in that several turbulence models were tested and the effect on flow dynamics is evaluated. In a second step, the most appropriate turbulence model was selected; the heat transfer from solid to fluid was studied (single phase heat transfer) and was then validated against the available experimental data in the literature. Thus the current work lays the foundations for a continuation of the work, for further optimization of the screw tube to be performed taking in to account the European DEMO conditions.

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