A coupled model for Helium flow along Eurofer cooling channels: practical implementation for TBM design

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Abstract

The ITER reactor is characterized by the high heat fluxes due to plasma direct radiation, and the neutron radiation generating volumetric heat sources. This heat is applied in transient pulses, and needs to be removed by the cooling system to keep the peak temperatures of the steel components sufficiently low.

In the case of the EU-TBM (HCPB and HCLL in Port#16 of ITER), the structural material is Eurofer97, which is cooled by Helium flowing through channels inside the material. The interest of the cooling is twofold: first, the temperature of the Eurofer hotspots must be kept below the material temperature limits given by the nuclear construction codes (for instance, RCC-MR); second, the temperature of the cooling Helium should be as high as possible to reach maximum efficiency of the hypothetical thermodynamic cycle of a gas turbine (the DEMO-relevance conditions).

Due to the physical properties of Helium and the pulsed nature of thermal loads in ITER, the temperature of the Helium varies notably along the ITER plasma cycle. The Eurofer channel wall temperature introduces temperature boundary conditions for the Helium flow, while the variation in Helium temperature affects the convection boundary conditions (film coefficient and fluid bulk temperature) for the Eurofer.

The 1-D transient fluid transport equations for a channel were discretized and implemented. The 3-D transient solid conduction problem (with convection boundary conditions at the channel surfaces) was solved using an off-the-shelf commercial FE code. The temperatures of the surface were transferred from the 3-D solid domain to the 1-D fluid domain with the help of a projection operator, while the film coefficient and the bulk temperature were transferred from the 1-D fluid domain to the 3-D solid domain.

Different numerical approaches and coupling schemes were designed to solve the discrete problem [1][2]. The methodology was further developed for the conceptual design phase as an in-house Fortran code for the 1-D domain, which was embedded in the commercial FE code Abaqus. The strategy was applied to the current design of EU-TBMs, where the evaluation of the C&S compliance (following RCC-MR, SDC-IC, …) of the Eurofer parts was performed. Complementary information about inlet/outlet temperatures of the Helium circuits, as well as global energy balances were obtained for several Helium flow conditions.

Keywords: **TBM, transient, channels, HCPB, HCLL.**

References

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