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Seminar

Institute for Plasma Research

Title : Study of Hypervapotron Cooling Phenomena Using CFD and Experiments for Neutral Beam Loading Scenarios

Speaker: Mr. Venkata Nagaraju Muvvala
ITER-India, IPR, Gandhinagar

Date : 23rd June 2020 (Tuesday)

Time : 03.00 PM

Venue : Online - Join the talk on Microsoft teams: [Join Microsoft Teams Meeting](#) (Use Google Chrome or Microsoft Edge browser, it doesn't require any login)

Abstract :

Neutral beam systems of the fusion machine require heat sink components to withstand the beam power densities in the range of 10-30MW/m². Hypervapotron (HV) element is the most promising and proven heat flux technology, wherein water-cooled heat sink elements provided with rectangular fins perpendicular to the flow and the cooling is mainly realized through boiling heat transfer. INTF [1] is one of such neutral beam testbed, where such HV elements, made from CuCrZr material, are incorporated for the water calorimetry purpose. The fin dimensions for this HV element are 4mm(H) x 3mm(W) with the cooling channel of 4mm(H) x 57mm(W) and the front plate with 4mm thickness. The operating conditions for INTF are Beam power densities 10-66 MW/m², flow: 30lpm & 60lpm at 10 bar.

The present study has been undertaken (1) to assess the heat transfer performance of the above-mentioned configuration with respect to the INTF operating condition (2) to determine the safe operating ranges (in terms of flow and peak power densities) and (3) to arrive at the conclusion on the apex angle suitable for that power density, in the design of calorimeter systems. This study has been performed utilizing three distinct approaches: (1) *A traditional FEA approach*, by programming empirical correlations available in the literature for different regimes of fluid (single-phase convection - Dittus-Boelter, nucleate boiling - Bergles & Rohsenow's). It is based on the solution of the steady-state heat diffusion equation for the solid domain (2) *CFD approach*, by performing steady-state conjugate heat transfer with multiphase flow simulation in 2D using ANSYS CFX, where three laws of conservation equations for each phase are solved which takes into account RANS turbulent models and boiling heat transfer models (3) *Experimental approach* on HV mockup at the High Heat Flux Test Facility at IPR to validate the computational results. The comparative study of all three approaches shows that the FEA approach gives better prediction compared to CFD and matches close to the experiment. The deviations (of 10 to 25%) in the results from CFD are observed to be due to the limitation in the boiling model correlations for the HV geometry.

The study showed that for the safe INTF operation, the incident beam power densities shall be below 9 MW/m² for the selected HV configuration and with working temperature limit 350°C for CuCrZr material. Further, this drove the design configuration of two calorimeter systems (the building block of HV elements) in the INTF, where two panels are arranged in V-shape configuration and the calculated apex angle is less than 41.8° and 7.8°.

Ref: [1] M.J. Singh, et al., R&D status of the Indian test facility for ITER DNB characterization, Nucl. Fusion 59 (2019) 096034, <https://doi.org/10.1088/1741-4326/ab1ff8>.
