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Design Studies towards the Geometrical Optimization of the Thermal-Hydraulic Performance of Cylindrical Hypervapotron-Type Collectors for Gyrotrons

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Gyrotrons are used in current and future fusion experiments to heat the plasma with microwaves in the electron cyclotron frequency range, as well as to drive with a non-inductive mechanism a non-negligible fraction of the plasma current. For example in ITER, the Electron Cyclotron Heating and Current Drive system will be made of 24 gyrotrons, operating at 170 GHz with an output power of ˜ 1 MW each.
The efficiency of the device is typically of the order of (at most) 50%, so that the rest of the power of the spent electron beam is lost to the inner surface of a hollow solid cylinder structure called the collector, typically cooled by water in forced flow. Several constraints characterize the collector design, e.g., the maximum allowable temperature, the minimum lifetime in terms of cycles related to fatigue, etc. Going towards the design and CW operation of higher power gyrotrons for the development of DEMO and future fusion devices, the issue of the heat load received by the collector must be carefully addressed. High performance thermal-hydraulic (TH) designs for the collector walls, using solutions like the hypervapotron (HV) geometry, widely studied in recent years for the cooling of plasma facing components, are being considered, together with ad-hoc sweeping strategies of the electron along the collector surface (longitudinal, transverse, combined), to make the thermal load as uniform as possible.
Here we concentrate on the investigation of a HV-like structure in a different geometrical configuration – the hollow cylinder of the collector. We apply the StarCCM+ commercial CFD code to the analysis of the effect of different aspect ratios (AR) of the HV cavities on the heat exhaust capabilities of a model collector, computing a self-consistent estimate of the heat transfer coefficient between collector and coolant, that will have to be implemented in the structural analyses of the collector walls for the fatigue and collector life time assessment. Starting from the deep cavities (AR ˜ 3), adopted as first reference geometry, an optimum TH performance of the collector can be achieved with shallower (AR ˜ 1) cavities, minimizing the maximum collector temperature. Also other possible geometrical configurations are considered, for instance zigzag structures, in order to assess the options for further improvements of the collector TH performance.

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