Self-consistent multi-physics modelling for the analysis of the working conditions in gyrotron cavities.

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Abstract

High-power gyrotrons, to be used in fusion reactors for EC resonance heating and current drive, should deliver a microwave power of the order of MW, at frequencies above 100 GHz, in long (seconds to hours) pulses. The radiofrequency waves are produced by the resonance interaction of an electrons beam and the magnetic field inside the gyrotron cavity, a hollow cylindrical region which is made by the resonator and, in case of very high power gyrotron under developing in Europe, the coaxial insert.

One of the technological factor that limits the performance development of the gyrotrons is given by the large ohmic load (~20 MW/m^2) that is deposited on the wall of the resonator, which requires to design a proper cooling strategy aimed to reduce as much as possible the temperature of the cavity to maintain the integrity of the structure. The thermal fields developed in the resonator and in the coaxial insert lead to non-negligible deformation of their surfaces. The deformation of the cavity, in turn, induces a variation of the frequency of the beam, and a variation of the ohmic load on the cavity surface.

The MUlti-physiCs tool for the integrated simulation of the CAvity (MUCCA) has been developed by Politecnico di Torino (PoliTo) and Karlsruhe Institute of Tecnhology (KIT) in order to assess the evolution of the working condition of the gyrotron cavity. The MUCCA tool couples a thermal-hydraulic (CFD) module to a thermo-mechanical module (both managed by PoliTo, and the latter to an electro-dynamic module (the code EURIDICE), managed by KIT. The electro-dynamic module is in turn coupled to the thermal-hydraulic module in a self-consistent, iterative simulation procedure.

Here we present the different models used in the multi-physics approach described above, together with their coupling. The validation path of the MUCCA tool to different gyrotrons currently under commissioning in Europe is also presented.

Keywords: **Gyrotron, thermal-hydraulic model, thermo-mechanical model, electro-dynamic model**