THERMAL FATIGUE OF DEMO FIRST WALL DUE TO PULSED OPERATION

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The effect of pulsing on the first wall of a future fusion power plant is manifested mainly as thermal fatigue of the structure. Due to the pulsing of the fusion power, temperature cycles are inevitable and result in varying stresses and strains in the first wall, which limit the lifetime as opposed to a steady-state mode where the number of heat-up and cool-down cycles is negligible.

There are papers considering dynamic effects of first wall designs (not restricted to DEMO) [1], but recent papers related to DEMO first wall [2, 3] seem to consider the steady-state operation mode only. This paper addresses the thermo-mechanical cycling of the DEMO first wall, as a precursor study with the ultimate intent of developing a sub-routine for the reactor systems code PROCESS, which will automatically adjust the design parameters of the first wall to accommodate different numbers of pulses between maintenance interventions.

In order to estimate the range of stresses and the expected lifetime, a series of analyses have been carried out on a "generic" DEMO outboard first wall. The finite element model is a section of the outboard first wall panel; the simplest possible individual model: a square-U bar of rectangular cross-section incorporating two parallel circular channels for coolant flowing in opposite directions. The thermo-hydraulic and thermo-mechanical analyses and optimization are carried out by ANSYS CFX and ANSYS Mechanical codes. This requires special attention to export the wall heat transfer coefficients from the first code into the second one in order to preserve sufficient accuracy in the thermo-mechanical analysis; the necessary accuracy was checked by analytical approximation. The objective was to determine the optimal thickness of first wall modules to achieve sufficiently low stresses for a pulsed version to survive the required design number of cycles in the plant lifetime. Both helium and pressurized water are considered as a possible coolant, and the wall structural material is low activation ferritic-martensitic steel (Eurofer 97).

It is assumed that one cycle lasts 8 hours and that the plasma facing surface of the wall receives a heat flux of 0.5 MW/m^2. Neutron heating at 25 MW/m^3 has been taken into account, as it leads to higher local temperatures. No other heat sinks are present, except the helium or water cooling. The stress and strain results are dominated by the thermal gradients however the means of supports can influence both mean and alternating stress.

Results were evaluated and changes were made to determine the extension of fatigue life by changing the geometry of the design (wall thickness, cooling channel diameter) and the coolant flow parameters (inlet temperature, coolant velocity). The calculations and results also indicate that more accurate data is required in respect of the fatigue and creep properties of Eurofer 97. The helium and water cooled results are compared and the challenges regarding both coolants are discussed.

This work was funded by the United Kingdom Engineering and Physical Sciences Research Council under grant EP/G003955 and the European Communities under the contract of Association between EURATOM and CCFE. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

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