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Influence of helium cooling channels on liquid metal magnetohydrodynamic flows in the HCLL blanket

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One of the blanket concepts proposed to be tested in ITER as part of the test blanket module program of the European Union is the helium cooled lead lithium (HCLL) blanket design. In this configuration steel boxes, called breeder units, are arranged in an array, separated by a stiffening grid, to form blanket modules. The deposited thermal energy is removed by helium flowing at high pressure and speed in channels integrated both in the walls and in cooling plates immersed in the liquid metal. These latter subdivide the breeder units into slender ducts where the lead lithium circulates under the influence of the strong plasma confining magnetic field. This gives rise to magnetohydrodynamic (MHD) phenomena whose effects on flow distribution have to be investigated to evaluate the performance of the proposed design. The established MHD flow is affected by the presence of helium channels in cooling and stiffening plates that results in non-homogeneous wall conductance.

In support to the conceptual study of a HCLL blanket, numerical investigations of fully developed MHD flows in breeder units have been performed, taking into account both the presence of helium channels inside stiffening and cooling plates, and the multi-channel effects due to the exchange of currents through common separating walls. It has been observed that when helium channels are located in walls perpendicular to the magnetic field internal parallel layers spread into the fluid yielding a non-uniform velocity distribution in the ducts. Moreover, when the cooling channels are present in the walls aligned with the magnetic field, velocity profiles in the parallel boundary layers show a ”wavy” behavior along field lines. Results have been compared with those obtained in the case in which cooling channels are omitted and the real thickness of the walls is scaled depending on the volume fraction of helium in the considered plate. This approach, based on the definition of an effective wall thickness, has been used in previous numerical studies as well as in experiments.