Liquid metal blankets and MHD issues

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The design of liquid metal breeding blankets for future fusion reactors represents a major engineering challenge due to performance requirements and severe operating conditions in terms of heat load and neutron flux. Liquid metal alloys such as lead-lithium are foreseen as heat transfer medium and coolant, and due to their lithium content, as breeder material to produce tritium, one of the fuel component for the fusion plasma. When the electrically conducting liquid metal circulates through the blanket structure, it interacts with the intense magnetic field that confines the fusion plasma leading to the induction of electric currents, which generate strong electromagnetic forces that act on the fluid. These resulting magnetohydrodynamic (MHD) phenomena influence remarkably the liquid metal flow behaviour and pressure losses in the blanket and hence dictate guidelines for a suitable design of the blanket [1] [2].

In the past, magnetohydrodynamic (MHD) flows for fusion blanket applications have been extensively investigated with focus on their fundamental features in generic geometries, such as pipes, ducts, bends, expansions, etc., that are common components of engineering systems. However, due to the complexity of fusion blankets, their conceptual study requires not only to predict MHD flows in single components, but also to take into account global effects, that arise when the full system is considered. This is of particular importance since electrical currents may pass across electrically conducting walls and these leakage currents couple neighbouring fluid domains as well as eventually the flow in the entire blanket system. Major MHD issues for the present European concept of a water-cooled lead-lithium (WCLL) blanket [3] are discussed by presenting both numerical and experimental studies. In this blanket concept, rectangular breeder units, arranged in poloidal columns, are fed with liquid metal and drained via long manifolds. It has been found that the design of the manifolds plays a critical role for reliable performance of a WCLL blanket. Solution strategies based on combined numerical and experimental analyses for determination of flow partitioning among breeding zones are described and an optimized manifold design is proposed.

References

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