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# Fast Flowing Liquid Metal Divertor Design Options: Experimental and Numerical Studies

*Tuesday, November 5, 2019 2:10 PM (30 minutes)*

A fast-flowing liquid metal (e.g. Lithium, Tin) divertor (FFLMD) is an attractive option that can take all (or almost all) the heat flux coming to the PFCs. A generic fusion reactor divertor with "fast"flow generally requires a ˜1-20 m/s speed with approximately mm to cm thickness. Balancing the heat flow into the divertor and carrying capacity of the liquid metal (LM) flow is the main requirement that sets the "fast"flow speed for the divertor. Such a divertor takes all the D/T particle flux and heat flux and allows substrate behind the liquid to be designed only for neutron fluxes. This permits the use of neutron-tolerant, low thermal conductivity, steels as substrates –an innovation which would greatly reduce material development for fusion. Among the challenges FFLMD concept need to overcome, the main one is the stabilization of the fast flow under MHD effects. In this presentation, we explain these effects and how to overcome them.

We present possible configurations including the fully toroidally connected annular FFLMD, toroidally segmented FFLMD, and arrangement of many "divertorlets,"small modular divertor systems. We explain how fast stable flow can be achieved in these systems and we explain the scaling laws for FFLMD technical requirements as the fusion reactor regime is approached. This theoretical analysis is then complemented with the experimental studies. We present the results and developments from the FFLMD experiments at Liquid Metal eXperiment, LMX, at PPPL and Liquid Metal FRee-surface EXperiment, LMFREX, that was placed in Oroshhi-2 in NIFS, Japan.

LMX studies the fast LM in a channel configuration with a magnetic field up to 0.33 Tesla and 2 m/s flow speeds. Heat transfer studies in LM found optimal channel surface shaping to obtain the maximum heat transfer from the surface that would minimize the evaporation in a reactor. The effect of surface shapes such as delta-wing and dimples at the bottom of the channel are shown experimentally and with numerical simulations. Running current through the LM for flow acceleration via magnetic propulsion and flow stabilization is studied experimentally. Analytical and numerical models of flow speed and wave variation are developed. This effect is used to control the hydraulic jump location.

LMFREX was placed in the Orosshi-2 facility to study LM flow in higher magnetic fields (3 Tesla). Under substantial vertical magnetic fields, MHD drag becomes a major problem for LM flow. We studied the effect of running poloidal currents, j, and showed that poloidal current can induce enough jxB force to overcome the drag and accelerate the LM to high speeds. This method can be used in a segmented LM divertor, which would allow running currents in toroidal direction, allowing FFLMD under vertical field conditions.

Finally, the next steps experiments that are needed to finalize the design of a FFLMD for reactor are discussed. FLIT, an upcoming torus device at PPPL that is designed to look at these issues under realistic conditions (1 Telsa and 10 m/s), is discussed briefly.

## Country or International Organization

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