Progress on Liquid Metal MHD Free Surface Flow Modeling and Experiments

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The use of flowing liquid metal with a free surface as a plasma contact surface have been the subject of a considerable amount work over the past several years in both the plasma physics and fusion engineering sciences programs. In particular, the ability of some liquid metals, like lithium, to pump hydrogen as well as getter oxygen and water impurities have made the use of *liquid surface technology* of interest to current plasma physics devices as potential particle control tools. In addition, fast flowing free surface liquid metals streams can also remove heat – making their application as a divertor particularly interesting for both near term and future experimental and burning plasma devices. Even for ITER, there is interest in the behavior of liquid metal melt layers in contact with plasma, which will exhibit some similar behavior to intentionally introduced liquid wall or divertor flows.

A key issue for the feasibility of liquid metal plasma contact surfaces is their magnetohydrodynamic (MHD) behavior. Liquid metals are, of course, good conductors of electricity. The electric currents that are self-generated from the liquid motion in the magnetic field, or externally-generated from their serving as closure paths for plasma thermoelectric and halo currents at points of plasma contact, can strongly influence the dynamics and surface shape of the liquid metal flow. Various phenomena are possible depending on the magnetic and flow conditions, including dramatic deceleration of the flow, deformation and deflection of liquid jets, and generation of high-speed droplets torn from the main flow.

This paper describes efforts toward the numerical and experimental simulation of liquid metal free surface MHD flows typical of the use of such flows for liquid divertors, especially in current or near term plasma devices. The 3D incompressible MHD free surface code HIMAG has been applied to several problems of interest. This unique code was developed to allow multiple solid and liquid phase materials with arbitrary geometry to be modeled. The inclusion of complex-geometry, electrically-conducting walls and nozzles are essential since electric current closure paths are typically through these solid structures. HIMAG has been used to analyze MHD flow experiments in the MTOR facility at UCLA and the LIMITS facility at SNL. HIMAG has also been used to analyze liquid metal pools in contact with plasma typical of the DiMES lithium exposure experiments in the DIII-D tokamak. These results are presented and compared with available experimental data. In addition, new experimental studies of wide channel liquid gallium alloy MHD flows in the MTOR facility have been conducted to investigate the effect of highly elongated flow geometry on the flow drag and surface shape. Initial results of this experimental campaign are also presented. Finally, plans for future experimental and numerical simulations in support of the flowing liquid divertor module for NSTX are reported and discussed.