Study of Liquid Metal Film Flow Characteristics under Fusion Relevant Magnetic Fields

Manmeet Narula, Alice Ying, Mingjiu Ni, Mohamed A. Abdou

Fusion Engineering Sciences, UCLA, Los Angeles, CA. manmeet@fusion.ucla.edu

The use of fast flowing liquid metal thin films as the divertor surface in a magnetic fusion device is a very attractive option for effective particle pumping and surface heat removal. The strong magnetic field environment tends to create flow disrupting magneto hydro dynamic (MHD) forces, which pose a major challenge in establishing a smooth, predictable flow of liquid metal over the divertor surface. The present study builds up on the ongoing research effort at UCLA, directed towards providing qualitative and quantitative data on liquid metal film flow behavior under NSTX [1] relevant magnetic field conditions and identifying design constraints for implementation of a liquid surface divertor module.

The study is being conducted at the magnetic torus (M-TOR) facility at UCLA, with capabilities to reproduce a scaled toroidal NSTX magnetic field environment. A Gallium alloy (Ga-In-Sn) is being used as the liquid metal. Preliminary experiments have been conducted using a 34 cm long and 5 cm wide stainless steel channel. The flow behavior has been qualitatively and quantitatively studied under different conditions of applied magnetic field and average fluid velocity. These experiments have lead to several interesting insights, most significant of them being a three to four times increase in the local film thickness as the flow progresses downstream, with a decrease in the average flow velocity by about 35%. It has also been observed that different magnetic field components have very different effect on the flow behavior. In order to build up on these preliminary findings, two new test sections have been designed. The first is a modification of the conducting channel being currently used, with added features of increased flow length of 42 cm and a stream-wise expansion of the channel span (from 5 cm at inboard to 7 cm at outboard). The second test section features a ‘wide channel’ flow of liquid metal (using a 20 cm wide conducting channel as opposed to the 5 cm wide current channel) under an applied surface normal magnetic field component, with a positive spatial gradient in the flow direction. This will lead to a better understanding of the flow behavior under an applied surface normal magnetic field component, while mitigating the hydrodynamic ‘wall’ effects. In order to supplement the experiments a conscious numerical modeling effort has been started. A 3D incompressible MHD free surface fluid modeling code called ‘HIMAG’ originally developed by HyPerComp Inc. is being modified for the problem at hand and will be used to get further insights into the physical phenomenon. Results from the new experiments and numerical modeling will be duly reported.

1: National Spherical Torus Experiment, an experimental fusion device being operated by the Princeton Plasma Physics Lab