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Experimental Studies of Liquid Metal Free Surface Flows

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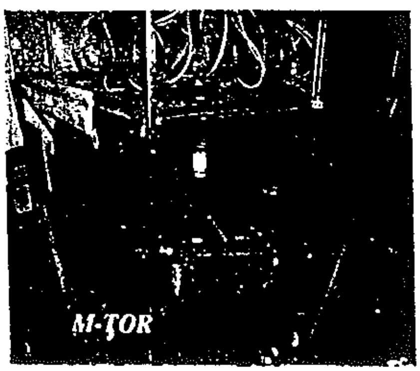
Abstract. A new experimental facility for studying liquid metal MHD flows with free surfaces is described. The facility is focused on studying the effects of complex magnetic fusion reactor fields and geometries on the liquid wall and divertor flows that have been proposed as part of the APEX and ALPS studies in the US fusion programs. Initial experiments in this facility are also presented and discussed including a new diagnostic technique for measuring free surface height with ultrasound transducers.

1. Introduction

The recent emphasis in the US fusion program on innovation has led to the initiation of the APEX [1,2] and ALPS [3] programs, commissioned to investigate high performance concepts for fusion chamber technologies. In particular, a good amount of this effort has been focused on self-renewing liquid walls for tokamaks and other magnetic plasma confinement schemes. Liquid metals like lithium, tin and their alloys, as well as gallium, are one general class of working fluid under investigation. But the utilization of free surface flows of liquid metals in such a capacity have a variety of feasibility issues related to the interaction of the flow with the magnetic fields. Much of the APEX work over the last couple years has been on design and modeling efforts to predict the behavior of the liquids in the complex fields of magnetic confinement fusion reactors [1-5]. There has also been past experimental work on this area in Russia, Latvia, Japan and the US, some of which has been summarized in [6]. But the current designs in the APEX study are very ambitious, seeking to cover the entire first wall and divertor with flowing *liquid walls*. It is plain that additional experimental studies are required that explore the interaction of complex magnetic fields and free surface flow geometies.

2. Apparatus

A new experimental apparatus has been developed at UCLA to begin exploring these liquid wall MHD interactions. The facility, called the M-Tor, is a 24 coil magnetic torus combined with a liquid metal flow loop currently using a room temperature Ga-In-Sn alloy. This facility employs components from the UCLA MeGA-Loop [7] as well as new power supplies, magnet coils, LM inventory, diagnostics that expand the capabilities of the previous facility. A view of the M-Tor facility, along with some important specifications are given in fig. 1.



<u>Stage 1</u>

- 24 coil torus, 80 cm ID, Aspect Ratio 2, $B_T \sim 0.6$ T
- Surface normal fields built with permanent magnets ($B_P \sim 0.1$ T)
- 15 liter Ga-In-Sn liquid metal flowloop with max flowrate ~3 l/s
- Applied electric currents > 1000 A possible.

<u>Later Stages</u>

- Toroidal field magnets run at full current, $B_T \sim 1.2$ T
- Flow loop upgrade to Li or Na alloy at ~25 l/s for large test sections
- Polodial field generation with pulsed conductors (simulate OH, vertical fields and plasma current)

Fig. 1: M-Tor LM-MHD Test Facility

3. Initial Experiments

The goal of this facility is to provide a test environment for investigating the effects of strong "fusion-like" fields and field gradients on LM free surface flows, including surface stability questions and the possibilities of active control of the liquid flows with applied electric currents. In addition, liquid wall geometric effects will also be studied, including inverted flows, flow with expanding/contracting flow areas, jet and droplet flows, and flows around penetrations.

Initial experiments are currently focusing on simple geometric cases of flow on an inclined plane with various separation distances between channel walls (see Figure 2). Initial data will be gathered for verification of models that predict flow profiles and film heights as a function of downstream distance. Flow height measurements are made using ultrasonic transducers [8] mounted on the back side of the channel. These transducers measure the time-of-flight for a sound wave to travel to the free surface and back, which when multiplied by speed of sound, give the film height at a given location as a function of time. Data from this first experiment in M-Tor is expected soon and will be reported in the full paper.

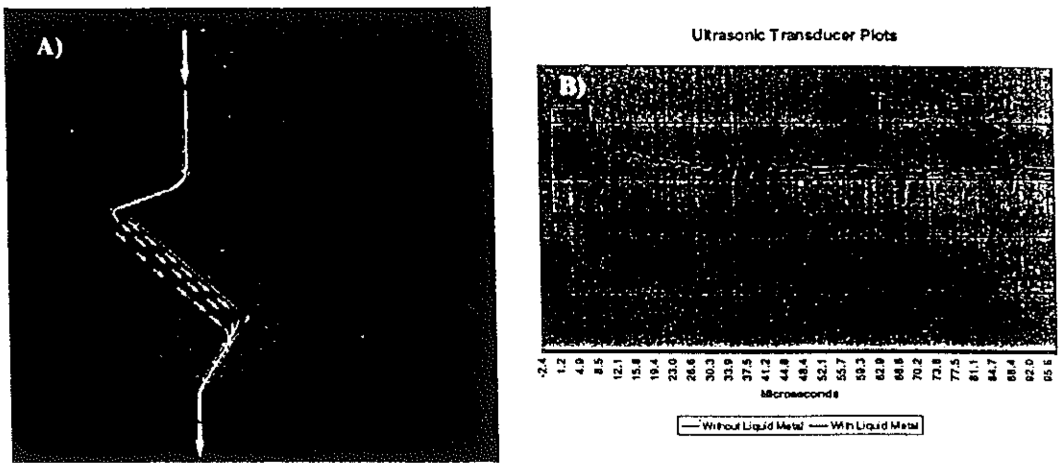


Figure 2: (A) Schematic of inclined plane test section and (B) example echo plot from ultrasonic transducer with and without liquid metal present

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