Seminar

Institute for Plasma Research

Title : Development of a two-phase detection probe for high temperature lead-lithium liquid metal applications

Speaker: Mr. Abhishek Saraswat
Institute for Plasma Research, Gandhinagar

Date : 30th March 2022 (Wednesday)

Time : 03.30 PM

Venue : Online - Join the talk: https://lobby.ipr.res.in/Abhishek_Saraswat_MSTalk

Abstract :

Liquid-gas two-phase flow is a common occurrence in various industrial applications. However, presence of a two-phase flow in a Liquid Metal (LM) breeder/coolant circuit for nuclear fusion applications may lead to critical issues including a reduced tritium breeding ratio, generation of hot-spots and improper nuclear shielding. Lead-lithium eutectic (Pb-16Li) has gained immense focus as a LM breeder for its various advantages and is utilized in several tritium breeding blanket concepts. Therefore, the development of a two-phase detection tool for PbLi LM environment is imperative. Numerous two-phase detection studies have been performed on room temperature/low melting LMs like GaInSn, Na etc. However, corrosive nature of PbLi coupled with high temperature operational constraints severely restricts the application of commercially available two-phase diagnostic tools in PbLi LM environment.

This work primarily aims to bridge the existing gap with the development and preliminary validation of a compact sensor probe to experimentally study two-phase flow regimes in PbLi LM environment. The scope of the present experimental work is primarily divided into three parts. The first part involves fabrication and utilization of an electrical conductivity based sensor probe with simultaneous imaging methods (videography) to estimate the bubble impaction chord length and time-averaged void fraction in water-air two-phase vertical columns. The second part is aimed at the development of an electrically insulating Al2O3 coating on SS substrates through experimental optimization of heat cure parameters. Further, rigorous validation of electrical insulation integrity in high temperature (300°C- 400°C) molten PbLi is performed for over 1300 h duration through in-situ measurements of Insulation Resistance (IR) along with estimations of volumetric electrical resistivity and temperature dependent IR de-rating factors. Estimated electrical resistivity remains within 109 -1011 Ω-cm for the investigated temperature range. Detailed metallurgical analyses are performed towards coating characterization to estimate the average coating thickness, LM ingress depth and surface morphology. The third part involves fabrication and calibration of a multivariable sensor probe to provide electrical conductivity based two-phase detection scheme with simultaneous two-phase bulk temperature measurements. The probe is employed for estimations of time-averaged void fraction, bubble frequency and average bubble residence time in molten PbLi-argon vertical column with bulk LM temperature up to 400 °C and timeaveraged void fractions up to 0.95, covering two-phase flow regimes from well-dispersed bubbly flow up to accidental scenarios like an in-box Loss of Coolant Accident. The experimental data corroborates high reliability and excellent temporal resolution towards individual bubble detection using electrical conductivity based measurements, while the coherent two-phase bulk temperature trends provide qualitative insights into the presence of two-phase flows. A decrease in the experimentally measured bubble frequency for timeaveraged void fractions above 0.6 indicates coalescence of bubbles in the PbLi environment.

Keywords: Liquid metal; two-phase; bubble; lead-lithium; electrical insulation; coating.