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Experimental Investigations on the Wetting Behaviours of Liquid Metals for Advanced Nuclear Applications

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Extended Abstract

Molten lead (Pb) and its alloys (such as PbLi and PbBi) find selective applications as preferred candidates for coolants, neutron multipliers and tritium breeders in advanced fission and fusion reactor concepts. A preference to these Heavy Liquid Metal (HLM) coolants is apparent from numerous technological advantages including a high boiling point, low vapor pressure, high thermal conductivity, relative chemical inertness and commercial availability [1-3]. However, molten Pb being an active corrodent presents a major issue in the form of selective leaching of elemental constituents from the structural materials over long operational duration, thereby jeopardizing the required integrity of critical components [4]. To protect the structural materials from such chemical corrosion and possible erosion in HLM coolant circuits, various high performing functional materials (such as ceramic oxide coatings) are being actively investigated to physically decouple the LMs from structural materials [5-7]. Another requirement for efficient operations of these complex HLM systems is an accurate measurement of process variables, including LM flow. Considering the deployment constraints on flow diagnostics in a high temperature, high magnetic field environment of fusion and advanced fission reactors with opaque LM flows, ultrasound transmission-based flow velocimetry is an attractive choice, performance of which heavily relies on a good acoustic coupling between the structural material and LM of interest. In fact, several researchers have highlighted the challenges and progress made with regard to the flow measurement using an ultrasonic technique for lead based melts [8-10].

Therefore, both the corrosion protection and the feasibility for deployment of critical diagnostics are severely impacted by the wetting behaviour of LMs under consideration. In this view, to advance the understanding of wetting behaviours focused on HLMs of interest towards nuclear applications, this work presents design of an experimental facility to facilitate estimation of Contact Angles (CAs) between different LMs (Hg, Ga, GaInSn, Pb) and horizontal stainless steel (SS-304) substrate. Room temperature melts (Hg, Ga, GaInSn) are utilized as surrogates to validate experimental methodology before proceeding to high temperature measurements on molten lead droplets at 425°C.

In this work, direct imaging technique is applied to various liquids (H_2O, Hg, Ga, GaInSn and Pb) to investigate their wetting interface with a mirror-polished SS-304 substrate. Quantified contact angles from direct imaging are compared against estimations made through Low Bond Axisymmetric Drop Shape Analysis (LBADSA) algorithm-based image-processing technique [11-12] for further corroboration. Comparison of results from the two techniques suggests a good agreement and the results are in coherence with previous studies. The preliminary experimental validation of developed test-facility allows its utilization to different LM-substrate pairs for which the database is either scarce or not available.

Design of in-house developed facility provides upgradation feasibility to adapt for higher temperature operations (> 500°C), using similar components. Future utilization of the facility is aimed towards assessing the wetting behaviours of molten lead and its alloys on different substrate materials including P-91, RAFM steels and Al_2O_3/Er_2O_3 coated substrates, both in controlled advancing and receding configurations to generate relevant database for applications in advanced nuclear technology development.

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