ABSTRACT

Boiling is an efficient mode of energy transfer in many industrial applications including power generation, refrigeration and air conditioning, cooling of electronic components and cooling of nuclear reactors. Nucleate boiling is usually the main heat transfer mechanism to remove heat from such systems because of its high latent heat of vaporization. Therefore, new methods to improve the thermo-physical properties of cooling fluids are of great interest to researchers. For decades, a lot of effort has been devoted to improve process efficiency by using more efficient heat transfer fluids. Nanofluid is a new type of functional fluid containing nanoparticles in a base fluid with enhanced thermal properties and better heat transfer characteristics. This enables them very attractive as heat transfer fluids in many industrial applications, especially for nuclear reactor safety systems. In particular, improvements in the safety margins are desirable to avoid a hypothetical severe nuclear accident. The reactor applications of interest could include use of nanofluids in the primary system, in the emergency safety systems as well as in severe accident management schemes.

Information regarding bubble dynamics during nanofluid flow boiling may provide valuable insight in the heat transfer mechanisms. Visualization of flow patterns could essentially help in understanding the heat transfer in nanofluid flow boiling because of the multiphase flow. The flow boiling heat transfer in nanofluids is more complex than that in the water due to unknown interfacial forces. The nanoparticle in the boiling nanofluids will produce effects on bubble generation, growth and departure. Therefore, the nanofluids flow boiling heat transfer coefficient and bubble behavior may be different from that of base fluids because of the collective effect of suspended nanoparticles. So far, the research of nanofluids flow boiling heat transfer is less and limited. Compared to the investigations on bubble structures leading to

various flow patterns in pure water, bubble behavior showing two phase oscillation has been less explored in experimental studies of nanofluids. Hence, the need arises for more intense experimental investigations to understand the mechanism of boiling heat transfer and flow pattern evolution of nanofluids.

This exploratory work is conducted to elucidate the parameters which influence the boiling performance of nanofluids. It aims to study the feasibility and performance enhancement of nanofluid-cooled system as well as to characterize the heat transfer behavior of nanofluids. It is an effort to advance the research towards thermal management of cooling of nuclear reactors. The purpose of this thesis is to contribute to a better understanding of the underlying physical phenomena in single-phase and specially boiling two-phase flow heat transfer of dilute oxide based nanofluids in a vertical channel.

In the present investigation, upward flow boiling through a vertical quartz tube for single nuclear pin has been investigated experimentally using pure water and nanofluids (Al_2O_3-water, TiO_2-water and SiO_2-water) with different concentrations. The effect of supplied heat flux (30-250 kW/m^2), mass flux (3-20 kg/m^{2}s), inlet subcooling (20, 40 and 60 K) and particle volume fraction (0.001%, 0.005% and 0.01% v/v) on heat transfer characteristics have been investigated**.** Visualization studies on the flow boiling heat transfer of water and nanofluids (0.001% and 0.01% v/v) have been conducted. Bubble growth, departure and the flow pattern evolution during flow boiling have been investigated with the aid of high-speed photography. The test conditions were set under various thermal hydraulic conditions in order to study the effects of several parameters that affect the bubble dynamics. Experimental results are analyzed, discussed and compared against results from similar investigations. Last but not the least, an effort was made to do CFD analysis of " flow boiling of nanofluids" using RPI (Rensselaer Polytechnic Institute) in

ANSYS Fluent using UDF (user defined function). However, outcome was not encouraging due to unknown interfacial mechanism. Hence, it was not presented in the thesis.

Results show that, various nanofluids have different optimum volume concentration in which the heat transfer characteristics show the maximum enhancement. The heat transfer coefficient for various nanofluids increases up to optimum volume concentration, and decreases thereafter. In case of nanofluids, *DNB has been delayed in comparison with water*. The nanoparticle deposition on the heater caused by microlayer evaporation keeps modifying the heater surface and alter the boiling phenomenon. This phenomenon is predominant at higher heat fluxes which causes delayed flow regime. It was observed that addition of nanoparticles delays the flow oscillation and the extent of suppression is proportional to nanoparticle concentration The amplitude of oscillation was less in nanofluids as compared to pure water. The presence of nanoparticles modified the bubble dynamics and reduced the void fraction at a given heat flux and thereby suppressed the oscillation.