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Bubble nucleation on the surface of the primary heat exchanger in a domestic central heating system

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ABSTRACT

The theoretical and experimental aspects of heterogeneous bubble nucleation are reviewed in the context of the micro bubbles present in a domestic gas fired wet central heating system. Such systems are mostly operated through the circulation of heated standard tap water through a closed loop circuit which often results in water supersaturated with dissolved air leading to micro bubble nucleation at the primary heat exchanger wall. This study will report the micro bubble nucleation in a standard domestic central heating system at typical operating conditions. Bubble nucleation rates have been calculated in the range of 0.3–4 bubbles/cm^2 s with total system bubble production rates measured in the range of 784–6920 bubbles per second. Bubble nucleation rates have been calculated through the consideration of the heat exchanger surface under super saturation conditions. The lack of experimental research in this area is evident from the non-existence of experimental correlations developed for similar physical scenarios where low levels of super saturation predominate. Hence, the classical nucleation models are considered inadequate for adaptation to the present study. A correlation through the application of the model for non-classical heterogeneous nucleation is proposed, based on the experimental data of the present study.

1. Introduction

Bubble nucleation due to supersaturated solutions, is a phenomenon present in a number of industrial processes such as the chemical, pharmaceutical, food and power generation industries. However, most of the research in this area has been purely theoretical in its nature. Hepworth et al. [1], attributed this lack of research to the difficulties in obtaining reliable experimental nucleation data and to the complex physical parameters that characterise systems where the nucleation phenomenon is observed. This is also due to the inherent difficulties in analysing two-phase mechanisms as outlined by Winterton and Munaweera [2].

Studies on bubble nucleation in supersaturated solutions done by Wilt [3], Lubetkin and Blackwell [4], Carr et al. [5] and Jones et al. [6,7] all reported that the nucleation rate was a very sensitive function of the degree of super saturation. The classical theory of nucleation is based on the theories for homogenous and heterogeneous nucleation in supersaturated solutions. Homogeneous nucleation is characterised by nucleation in the bulk of a homogenous solution and heterogeneous nucleation is characterised by nucleation in a pit in the surface of a container, on a molecularly smooth surface or on a particle in the bulk fluid. Jones et al. [6] reported that super saturation levels in excess of 100 are required for both classical forms of nucleation. However, studies done by Wilt [3] for CO_2 and H_2O solutions reported that super saturation levels between 1100 and 1700 are required for homogenous nucleation at room temperature whereas Lubetkin and Blackwell [4] reported that heterogeneous nucleation was observed in H_2O and CO_2 solutions with much lower super saturation levels between 2 and 8.

Jones et al. [6] reported that the classical nucleation models as initially developed by Blander and Katz [8] do not represent the nucleation phenomenon in many practical systems. This is due to the relatively low super saturation levels observed, these being less than 5, where the nucleation energy for each gas cavity is much lower than for the classical case. In their study, Jones et al. [6] attributed nucleation in low super saturation solutions to the presence of pre-existing gas cavities. This concept was shared by many, including Dean [9], and more recent studies by Hepworth et al. [1]. Jones et al. [6] also reported that most nucleation events observed in research are due to this phenomenon. They refer to this type of nucleation as

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