# Enhancing Reactor Safety Via Dynamic Modeling of Bubble Transport

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Bubbly flow

Cap-bubbly flow

Turbulent cap-bubbly flow

Churn-turbulent flow

Figure 1. Different types of bubbles and interfacial structures in various two-phase flow regimes. Images are captured from air-water two-phase flow in rectangular flow channel.

**Bubbles may not be something that cross your mind when you think about reactor safety.** In fact, most people are not aware that the bubble transport is one of the key phenomena to consider in designing, operating, and assessing nuclear reactors.

Since bubbles can be various sizes and shapes under different flow conditions (see Fig. 1), the interfacial structure of gas bubbles in a liquid flow is directly related to the hydrodynamic characteristics of the coolant flow and its ability to cool. Thus, bubbles play an important role in reactor safety analysis during postulated accident scenarios. As a result, much research on two-phase flow phenomena has been led by nuclear engineers as well as researchers in other engineering fields.

The traditional approach in treating two-phase flow phenomena has been to develop experimental correlations specific for certain two-phase flow regimes. These regime-dependent correlations are implemented into numerical codes, where the boundaries between regimes are specified through static regime transition criteria. Such an approach, however, does not represent the true dynamics of two-phase flow, where the interfacial structures continuously evolve via various bubble interaction mechanisms. This limits the accuracy of code predictions and imposes wider safety margins in reactor operation.

In view of enhancing the accuracy of code predictions and, in turn, reactor capability, Dr. Seungjin Kim, assistant professor of mechanical and nuclear engineering, has been studying a new dynamic approach employing transport theory. The interfacial area transport equation dynamically predicts the evolution of interfacial structures in two-phase flow by mechanistically modeling various bubble interaction phenomena. This eliminates artificial bifurcations and numerical oscillations in the code calculations stemming from the use of conventional flow-regime-dependent correlations and regime transition criteria.

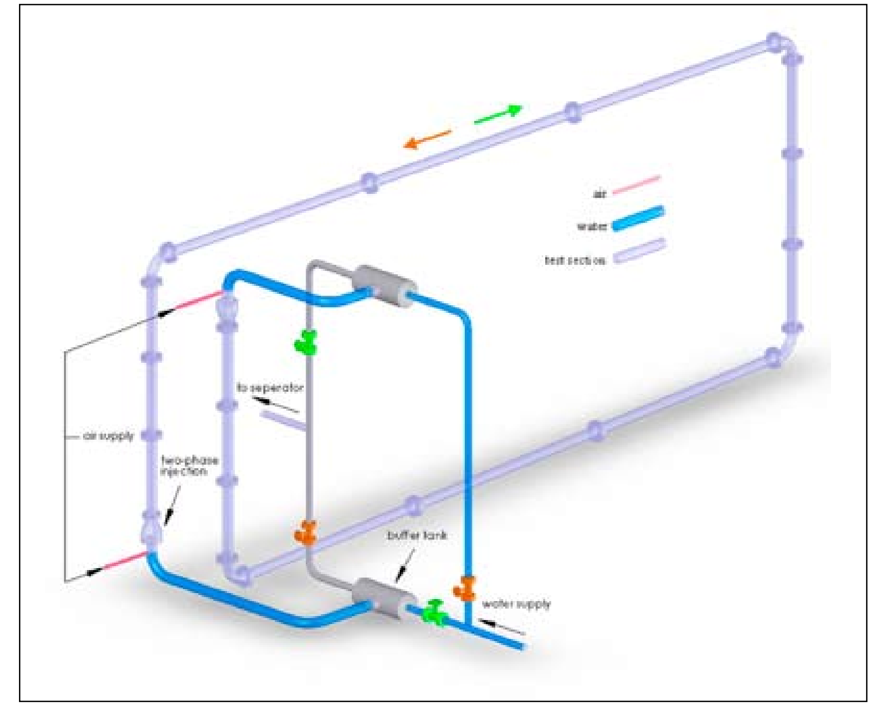


Figure 2. Isometric diagram of the air-water two-phase flow test loop being built in the Advanced Multiphase Flow Laboratory (AMFL). The vertical and horizontal test sections are approximately 4 and 8 meters long, respectively. The test loop is designed to be capable of all conceivable vertical-horizontal flow configurations through a simple control of valves. For example, the flow moves in the direction of the green arrow when the green valves are open and the red valves are closed, or vice versa. The data acquired in this facility will be used to study geometric effects in two-phase flow transport.

This new approach is consistent with recent efforts led by the U.S. Nuclear Regulatory Commission (NRC) and the Idaho National Laboratory (INL) to improve the existing codes. Furthermore, since two-phase flow is often encountered in engineering systems, this method has the potential to make a significant impact in many other engineering fields as well. These applications may include conventional heat transfer systems, combustion engineering applications, space or microgravity applications, fuel cell applications, and the development of multiphase computational fluid dynamics codes.

At the newly established Advanced Multiphase Flow Laboratory (AMFL), Dr. Kim and his research group are engaging in research projects related to interfacial area transport, supported by the U.S. Department of Energy (DOE) and the NRC. The research focuses on the geometric effects in the development of interfacial structures (Fig. 2) and the multidimensional phenomena in two-phase flow transport (Fig. 3). Upon completion of these studies, a more robust model applicable to practical two-phase flow systems can be established.

(a) Center-peaked

(b) Skewed

(c) Wall-peaked

Figure 3. Bubble transport under different inlet void conditions for separate-effect studies. Each inlet configuration highlights different multidimensional effects in two-phase flow transport, such as turbulent diffusion, wall effects, lift, and drag.