Prediction of void fraction in liquid-gas flow using gamma-rays

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When the heat is transferred to a coolant inside a heat exchanger, bubbles can be formed due to the nucleate boiling. The excess heat, the nature of the tubes surface and the thermophysical properties of the fluid contribute to the growth and dynamics of the steam bubbles, influencing the heat transfer coefficient. Therefore, this report presents a methodology to estimate void fraction using the principles of gamma densitometry in a two-phase flow. A mathematical model of the evaluated flow regime was developed using the MCNPX code in order to obtain a proper geometry and then use an artificial neural network. The method is based on the attenuation of a monoenergetic gamma-ray transmitted beam that crosses a sample and the signal is recorded by a detector. Fluids with high density cause a decrease in the count rate at the detector, while fluids with lower density increase in the count rate. The calculation of fluid volume fraction in heterogeneous two-phase systems under bubbles flow regime using the gamma attenuation technique can be performed using Equation 1.

$$\alpha_g = \frac{\ln{(I/I_w)}}{\ln{(I_g/I_w)}}$$

Equation 1

Where:
α_g: gas volume fraction (void fraction);
I: intensity of transmitted gamma rays with tube containing water and gas;
I_w: intensity containing only water;
I_g: intensity containing only gas.

The simulated geometry developed with the MCNPX code is shown in Figure 1, and consists of a 30 cm iron tube with 30 cm of external diameter containing, initially, just liquid and, later, liquid and steam bubbles. 1.5×1.5″ NaI(Tl) detector composed of an aluminum shell and a magnesium oxide reflective layer, with an isotropic Cesium point source (662 keV) is also shown in Figure 1. Steam bubbles were simulated in several positions (P_n) inside the tube to assess the sensitivity of the model.

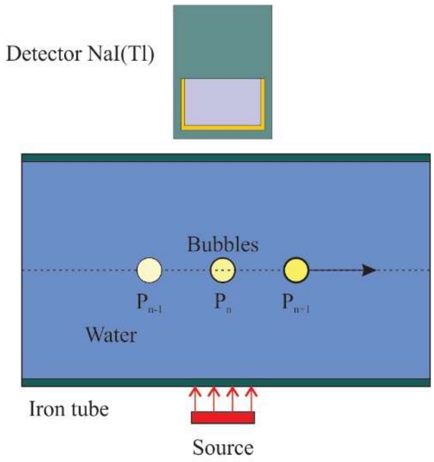

Figure 1. Simulated geometry.

The results referring to flow of steam bubbles in front of the detector are shown in Figure 2. For the movement of the bubble, only variation in the longitudinal axis of the tube was considered. Signal change may be noticed when the steam bubble enters on the solid angle of the gamma-ray beam. It is worth mentioning that this depends on the radius of the bubble, however, this can be compensated by changing the value of the energy of the source.

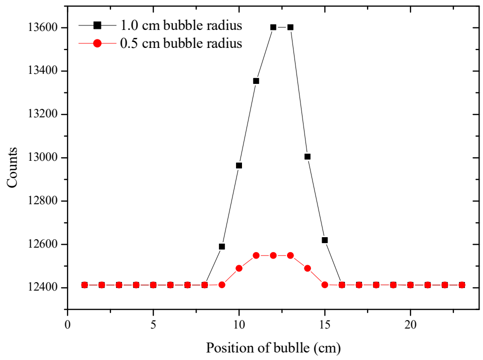

Figure 2. Processed data from MCNPX simulations.

The recording of the signal in the detector is proportional to the transmission of gamma-rays due to the flow inside the tube. An algorithm based on artificial neural networks will be used to correlate the fluid density information with the void fraction.

References

[1] PELOWITZ, D. B. "MCNPX TM User's Manual," Version 2.5.0, LA-CP-05-0369, Los Alamos National Laboratory, 2005.