Study of salinity independent volume fraction in multiphase flow using artificial neural networks

C. M. Salgado[1], L.E.B. Brandão[1]
e-mail: otero@ien.gov.br, brandao@ien.gov.br

[1] *DIRA, IEN*

Keywords: salinity, volume fraction, MCNP-X code, artificial neural network, gamma-rays

This report investigates the response in material volume fraction (MVF) prediction system for water-gas-oil multiphase flows considering variations up to 16% in salinity of water. The approach is based on the pulse height distributions (PHD) pattern recognition by means of an artificial neural network (ANN) [1]. Theoretical models for annular and stratified flow regimes have been developed using MCNP-X code to provide data for the network. The gamma-ray PHDs obtained by the detectors are directly used to feed an ANN. The detection geometry consists of two NaI(Tl) detectors, the first one positioned at 180°, diametrically opposed to sources (^{241}Am: 59.45 keV and ^{137}Cs:662 keV) and the second one at 45°. In addition, the proposed geometry combines the transmitted and scattered (dual-mode densitometry) beam measurements. One collimated (angle beam 8.84°) gamma-ray point source has been simulated in the MCNP-X code. The characteristics (energy resolution, efficiency, dimensions) of real detectors are also considered; in general, the model presented tends to approach the realistic case. The dual mode densitometry method demonstrates high sensitivity to the salinity of the water component mainly at low energy gamma-ray due to the relatively high atomic number of chlorine modifying the photoelectric absorption [2]. This is illustrated in Fig. 1.

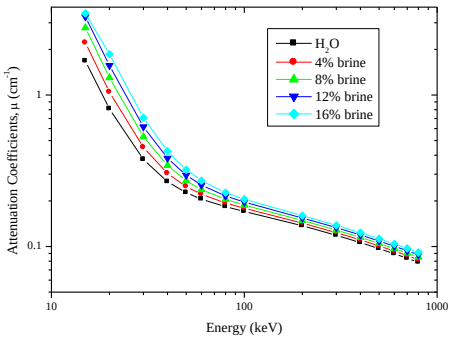

Figure 1. The linear attenuation coefficients of brine at different salinities.

In a multiphase flow with brine, oil, and gas the salt atoms will give a relatively large contribution to the average atomic value of the mixture since the main components of the flow are low atomic number atoms (H, O and C). These values were also obtained by MCNP-X code using brine consisting of NaCl mixed by weight (w/w) with water. The linear attenuation coefficient values of water and oil present major differences in low energy gamma-ray which allows for the distinction between oil and water. The ANNs performance of the MVF predictions is summarized in Table 1. 94% of all the data were predicted within an error margin of ±10%.

Table 1. Summary of pattern recognition for the prediction results.

Success rate	Annular		Stratified	
	air	water	air	water
≤ 5%	94.52	77.51	97.16	82.61
5 a 10%	3.02	17.01	1.89	12.48
10 a 20%	2.27	4.35	0.57	4.35
< 20%	0.19	1.14	0.38	0.57
r^2	1.000	0.998	1.000	0.999

r^2: linear correlation coefficient

Due to the differences found between the PHDs for each one of the brine mixtures of volume fractions, it was possible to design an ANN that resulted in good prediction for a total of 529 data. The results for all validation tests presented maximum average relative errors of 1.25% for air and 3.39% for water, demonstrating a good agreement between the actual and the predicted values of MVFs. The results indicate that the methodology can be used for the determination of MVFs in annular and stratified water-gas-oil multiphase. The linear attenuation coefficients of brine at different salinities are being determined for the validation methodology.

References

[1] SALGADO, C. M. et al. Salinity independent volume fraction prediction in annular and stratified (water-gas-oil) multiphase flows using artificial neural networks. **Progress in Nuclear Energy**, Oxford, v. 76, p. 17-23, 2014.

[2] JOHANSEN, G. A.; JACKSON, P. Salinity independent measurement of gas volume fraction in oil/gas/water pipe flows. **Applied Radiation and Isotopes**, New York, v. 53, p. 595-601, 2000.