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Gamma-Ray attenuation method for void fraction measurement in Liquid-Liquid flow

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ABSTRACT

Void fraction measurements are made by the gamma radiation method in crude oil-water two phase flow. To measure the void fraction, the required gamma-ray source and the strength of the source is experimentally found for oil-water two phase flow using Cs^{137}.This is achieved by the empty small plastic tubes were used for simulating the void fraction through the mixture. The obtained results show that, the void fraction value increase with the source count rate by the NaI (Tl) counter.

Introduction

The measuring and predicting the average density, pressure drop, flow pattern, etc. of a flowing two-phase flow mixture in pipes is the void fraction [1-3]. It is equal to the ratio of the volume of oil to the total volume of oil-water mixture in a finite length of the pipe line. One of the methods used for void fraction measurement is the radiation attenuation technique.

Many various investigators used the radiation attenuation technique to determine the void fraction in two-phase flow [5, 6]

In this work used Gamma-Ray beam to measure the average void fraction of oil mixed with water experimentally.

Experimental measurements

The photographic arrangement as shown in Fig.(1), for experimental apparatus for void fraction measurement based on allowing a collimated beams of gamma-ray to traverse the cross section of the pipe. The radiation source is positioned diametrically on the opposite side of the NaI (Tl) detector.

The attenuation of a beam of radiation when passing through oil-water medium of path length (L) is given by:

$$I(t) = I(o)\exp\left[2\mu_w x + \mu_T L\right]$$

Where I Intensity of the radiation passing without interaction with the medium (cm^{-2}. sec^{-1}), I_o Intensity of the radiation incident on the medium (cm^{-2}. sec^{-1}), μ_w the linear attenuation coefficient of the material of the pipe wall (cm^{-1}), x Thickness of the pipe wall (cm), μ_T Total linear attenuation coefficient of the oil-water mixture (cm^{-1}).

The total linear attenuation coefficient of the radiation interaction with the oil-water mixture is:

$$\mu_T = \alpha\mu_{oil} + (1-\alpha)\mu_f$$

Where α void fraction, μ_{oil} linear attenuation coefficient of oil (cm^{-1}), μ_f linear attenuation coefficient of water (cm^{-1}).

A Pyrex beaker with inner diameter (8.3) cm and (0.15) cm thickness was filled with water. Small diameter (0.6) cm, empty, plastic tubes were used for void simulation by inserting them into the Pyrex beaker (an arrangement of relevance to droplet flow).

I_{oil}, I_f and I detector readings were taken with the empty plastic tubes immersed in the water filled Pyrex beaker. This was done for every time a certain number of plastic tubes were used to get the actual value of void fraction from the mock-up arrangement. The extreme case of droplet flow was also simulated by filling the plastic tubes with water and putting them into the empty Pyrex beaker. This method ensures that the thickness of the plastic tubes was canceled.

The experimental arrangement for measuring the volume fraction consists of a Cs^{137}gamma-source with 0.636 µci activity and NaI (Tl) detector has 7.62 cm outer diameter and 7.62 cm active length.

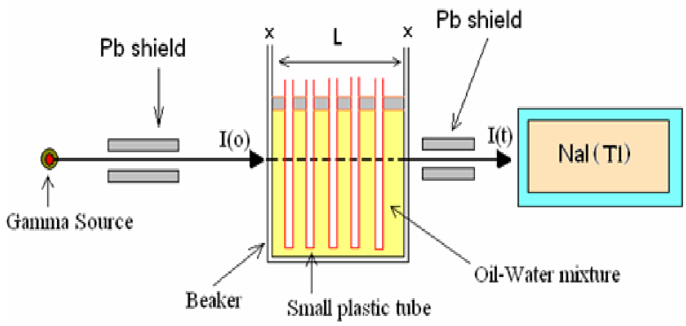

Fig (1): geometrical arrangement of void fraction measurement

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Results and discussion:

The changing of the count rate with void fraction as shown in Fig. (2), when pyrex tube filled with water and plastic tubes are empty. From which, one can observe that the ray count rate is increasing with increasing the void fraction (number of empty plastic tubes) until it becomes constant, approximately (24200 count/1 min) at a value of void fraction equal to (0.07).

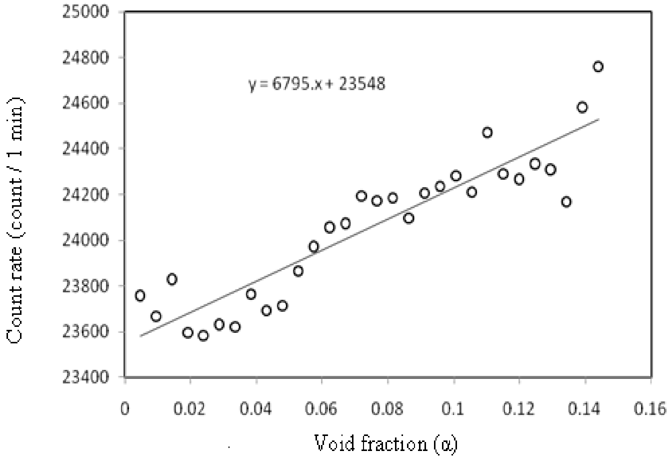

Fig. (2): Experimental results of count rate versus the void fraction (α) in case of pyrex tube filled with water and plastic tubes are empty

Fig. (3) Was the same as Fig. (2), but a pyrex tube filled with crude oil and the plastic tubes are empty. From which, one can observe that the ray count rate is increasing with increasing the void fraction (number of empty plastic tubes) until it becomes constant, approximately (40600 count/1min) at a value of void fraction equal to (0.08) then the ray count rate again increases with increasing the void fraction until it becomes constant, approximately (41300 count/1min) at a value of void fraction equal to (0.13).

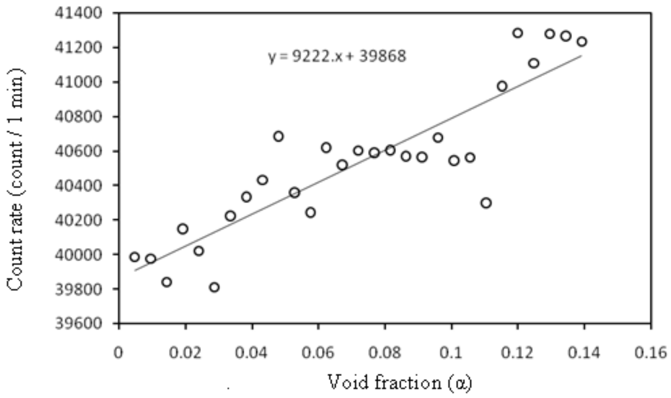

Fig. (3): Experimental results of count rate versus the void fraction (α) in case of pyrex tube filled with crude oil and plastic tubes are empty

Fig. (4) refers the variation of count rate with the volume of the oil-water mixture, in which the pyrex tube filled with the water and the small plastic tubes filled with the crude oil, in which the count rate was increasing with increasing the void fraction of the oil-water mixture, which is the count rate started at a value equal to (18500 count/1min) and the void fraction at value (0.01).

Fig. (5) was the same as in Fig.(4)but the pyrex tube filled with the crude oil and the small plastic tubes filled with the water, it shows slow increasing of count rate with increasing the void fraction, in which the count rate started at the value equal (29000 count/1min) and the void fraction at a value to (0.01).

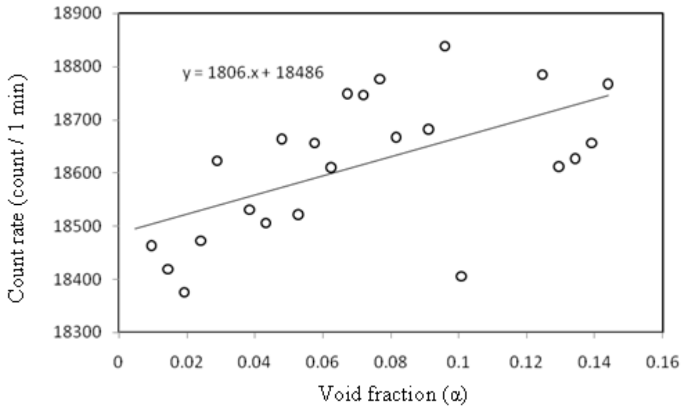

Fig. (4): Experimental results of count rate versus the void fraction (α) in case of pyrex tube filled with water and plastic tubes filled with crude oil

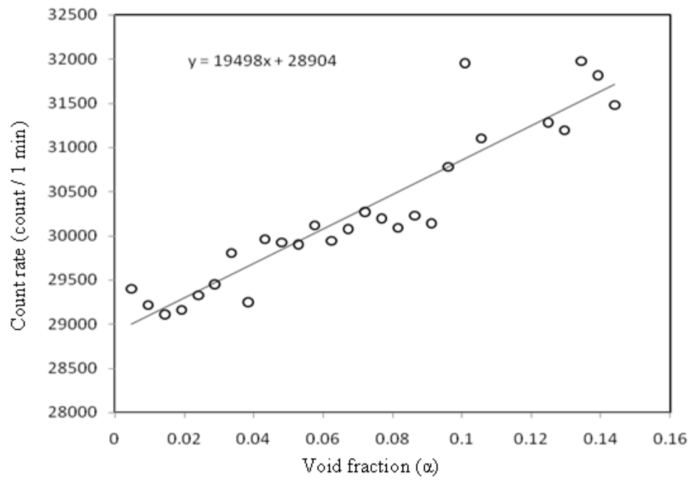

Fig. (5): Experimental results of count rate versus the void fraction (α) in case of pyrex tube filled with crude oil and plastic tubes filled with water

Conclusion:

The used radiation attenuation technique has many advantages, which is [7]:

1- Relative easiness of the calibration method.

2- No physical contact of probes with the two-phase flow medium; this avoids flow perturbation.

3- There are many errors in the readings due to the out photons from the radiated source are arbitrary measurement. To correct this type of error repeats the readings and take it's averages.

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