Evaluating the water flow profile in a pipeline measuring the residence time distribution

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Keywords: radiotracer, flowmeter, oil.

Published firstly by Danckwerts in 1953[1], the Residence Time Distribution functions, RTD, are one of the most effective process for the evaluation of industrial plants and to study the movements of fluids inside pipes. Associating the probabilistic formalism of RTD with the possibility of gamma radiation pass through to the solid mater, complex flow patterns inside pipes can be easily monitored using a specific radioactive tracer and measuring the its movement through the unit.
The technique of RTD functions considers that each particle, when is moving through the unit, interacts and undergoes to all the physical/chemical process, so each portion has its "history", with its time inside the unit defining a function of probability distribution E (t), function age.
Considering a particular volume element of the fluid moving through the unit, its "age" is defined as the instant of time since it enters the unit and any instant of time t and as the "residence time", τ, the total time since it enters and leaves the unit. Normally is used the reduction time $\theta = t/\tau$.
Measuring correctly the RTD curves contribute to identify the behavior of flow inside the pipe and is essential to model the fluid movement.
When a fluid is transported through a pipeline, there is a radial variation in the mean velocity of different portions of the fluid because the central part of the fluid moves with a mean velocity greater than the mean velocity of the part near the pipe wall.
This fact is associated to the chemical/physics proprieties of the fluid as well as to the characteristics of the duct wall.[2], because the radial profile of axial velocity results in axial mixing and the radial diffusion contributes to the radial homogenization of fluid near-wall region.
In this work was studied the case of single aqueous phase. The experimental data were measured in the aqueous pipeline; PVC ducts, internal diameter equal 2.05 cm, with different flowrate. Two scintillator detectors were positioned separated by 17 cm. and used to measure the mean velocity v and RTD curves, show in figure 1. Three different flow models were used to fit the experimental data to the F (t) function:

- Axial dispersion with low dispersion

$$E(\theta) = \frac{1}{2}\sqrt{\frac{P_e}{\pi}}\, e^{-\left(\frac{P_e}{4}(1-\theta)^2\right)}$$

- Axial dispersion with high dispersion

$$E(\theta) = \frac{1}{2}\sqrt{\frac{P_e}{\pi\theta^3}}\, e^{-\left(\frac{P_e}{4\theta}(1-\theta)^2\right)}$$

- Perfect mixer flow injection t=0

$$E(\theta) = e^{-\theta}$$

- N perfect mixer in series

$$E(\theta) = \frac{N^N}{(N-1)!}\theta^{N-1}e^{-N\theta}$$

The result model adjusted for detector D1 is show in figure1, where is proved a stratified flow profile water moving through the pipeline: the flow is composed by three different components, a fast one, the axial dispersion1, another less intense and slower also axial dispersion and a very slow perfect mixer type.

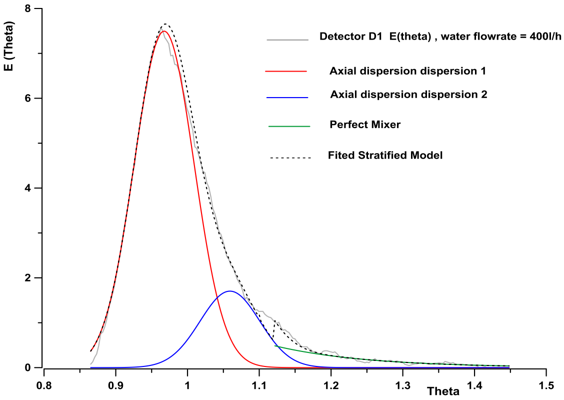

Figure 1. Experimental RTD E(theta) for water

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