A new method for estimation of the transient time using Fourier transform associated with cross-correlation techniques to measure flow rate in pipelines using radiotracers

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Cross-correlation techniques constitute a robust methodology to measure a system impulse response in pipelines and measure flow rates [1,2,3].
This work presents a measuring device using four scintillator detectors, D1, D2, D3, and D4, to measure oil flow rates in a pipeline using the cross-correlation technique.
In a pipeline, the flow rate Q is a simple product of the internal pipe area A and the velocity measured using the transient time between two sensors. The velocity $\bar{v}$ is calculated by measuring the correlation delay directly from the maximum of the cross-correlation function (CCF).
For the signal recorded by the detectors, the CCF is estimated by the equation of convolution (1):

$$CCF_{XY}(t) = X(t) \otimes Y(t) \quad (1)$$

X (t) – signal recorded by D1
Y (t) – signal recorded by D2

Using the Fourier transform, the equation (1) is:

$$CCF_{XY}(t) = F^{-1}[X(S).Y(S)] = F^{-1}[H(S)]$$

Digite a equação aqui.
X(S) – Fourier transform of the signal x(t).
X(S) – Fourier transform of the signal y(t).
H(S) – convolution between signals X(t) e Y(t).

The correlation coefficient $\rho_{XY}(t)$ is:

$$\rho_{XY}(t) = \frac{CCF(t)}{\sqrt{CCF_{XX}(0).CCF_{YY}(0)}} \quad (3)$$

$CCF_{XX}(0)$ – auto-correlation function of X (t).
$CCF_{YY}(0)$ – auto-correlation function of Y (t).

After applying (2) to compute cross-correlation functions, the transient time τ between the signals recorded by two detectors is equal to the time in the maximum of the ρ_{XY} (t) curve, the correlation coefficient curve, equation (3). Figure 1 is shown the curves using as radiotracer oil labeled with ^{123}I and registered by four scintillator detectors in the experimental flow rig (internal diameter equal to 2.095 cm) and Q = 800 l/h. Our correlation flowmeter combines the data for all the detectors, resulting in six values measured for the flow velocity. Table 2, the result using the Cross-correlation Method.

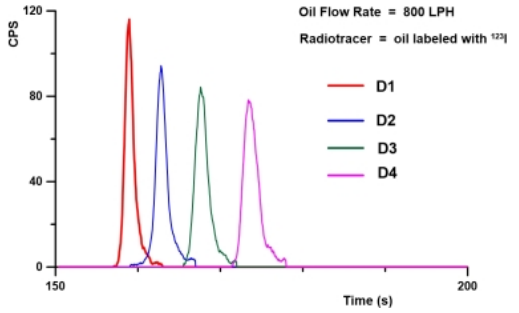

Figure 1: Residence time curves for D1, D2, D3, and D4; oil flow rate = 800 LPH

Table 2: Oil flow rate using Cross-correlation.

Method 2 – Cross-Correlation Coefficient		
	Transient Time (s)	**Flow Velocity (cm/s)**
D1D2	$3.92 \pm 2.35 \times 10^{-3}$	65.09
D1D3	$8.72 \pm 1.86 \times 10^{-}$	65.07
D1D4	$14.66 \pm 5.67 \times 10^{-3}$	64.98
D2D3	$4.85 \pm 2.16 \times 10^{-3}$	65.41
D2D4	$10.81 \pm 1.51 \times 10^{-3}$	64.54
D3D4	$5.94 \pm 7.53 \times 10^{-3}$	64.01
Mean Flow Velocity (cm/s)		(64.85 ± 0.73)
Flow rate (l/h)		(804.77 ± 8.22)

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