DROP SIZES OF EMULSIONS IN CYCLONIC-BASED VALVES

C. A. Fernandes, R. F. Ribeiro, J. B. R. Loureiro & A. P. Silva Freire
Mechanical Engineering Program, Federal University of Rio de Janeiro (COPPE/UFRJ), Brazil

Abstract The present work assesses the performance of a cyclone-based valve that has been designed to improve the separation efficiency of oil-water mixtures. The cyclone-based valve has a especially designed stem, fitted with flow deflectors (guides) to enhance centrifugal effects. The stem is followed by a conical section that reduces droplet break up by turbulence and shear, favoring downstream flow separation. Droplet distributions for low oil-in-water concentrations are investigated. Results are compared with measurements carried out downstream of a gate valve, set to work on the same operational conditions. Measurements of particle size distributions are performed through three techniques: Focused Beam Reflectance Measurement (FBRM), Shadow Sizing Technique (SS) and Phase-Doppler Anemometry (PDA). Measurements in the outlet cyclone through Laser-Doppler Velocimetry (LVD) and Particle Image Velocimetry (PIV) are made to understand the opposing roles of break up (turbulence and shear) and coalescence effects (centrifugal forces).

INTRODUCTION

Many producing oil fields operate with very large water concentrations. Recovery mechanisms that resort to water injection are commonly used and have the typical feature of increasing the water/oil ratio of producing wells. Under this condition, available separation processes must be very efficient to ensure the economic viability of operations.
A difficult problem with production and processing facilities is that their control depends ultimately on a system of valves. The high turbulence and shear in control valves provoke strong mixing and efficient dispersion (emulsification) in liquid-liquid systems.
The present work discusses a new type of valve, a cyclonic valve, that has been specially design to work with low oil-in-water concentrations. Previous concepts of cyclonic valves (Husveg et al. 2009) have striven on developing geometries where the pressure drop occurs gently on the axial direction. These valves have an extended axial length, with a contracting cyclone fitted in the inlet region and a second diverging cyclone in the outlet region. The extended length is expected to provoke a reduction in ϵ (mean turbulent energy-dissipation rate per unit mass) and an increase in droplet size trhough the relation $d_{max} = W_{e_{crit}}^{3/5}(\sigma/\rho_c)^{3/5}\epsilon^{-2/5}$. Centrifugal forces generated in both cyclones are expected to facilitate droplet coalescence.
In the present design (Figure 1), one cyclone is used in the outlet region, downstream of the region where the major pressure drops occur. The valve stem – which regulates the pressure losses – is fitted with flow deflectors (guides) to enhance centrifugal effects. Both new features, the flow deflectors and the outlet cyclone, are expected to yield combined effects that have a positive impact on oil-water separation.
The work of Husveg et al. (2009) analyzed droplet size distributions through an off-line technique. Here, two different techniques are used to obtain in-line real time distributions of droplets: Focused Beam Reflectance Measurement (FBRM) and Phase-Doppler Anemometry (PDA). A critical assessment of both techniques is also made.
The present work further resorts to Laser Doppler Anemometry (LDA) and Particle Image Velocimetry (PIV) measurements in the outlet cyclone to characterize the flow field. The purpose is to understand the basic mechanisms of drop break up and relates them to the actual geometry of the valve. Shadow sizing Technique is used to observe the flow downstream of the cyclone.

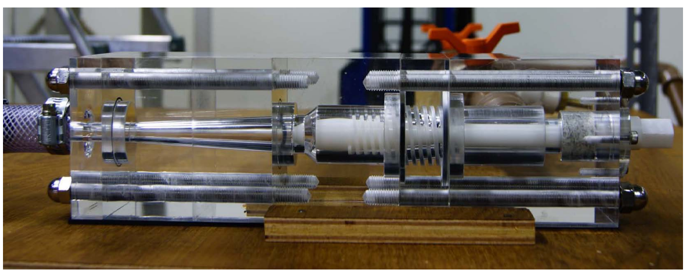

Figure 1. Geometry of the cyclone-based valve.

DROPLET SIZE DISTRIBUTION

Droplet size distributions were obtained considering identical flowrates and pressure. The experiments were conducted at the Laboratory of Compact Separators (LSC/PEM/COPPE/UFRJ) in a real scale cyclonic valve (Figure 1) and in a reference control valve, a gate valve. Water and mineral oil (Eureka 10) were the working fluids. The present experiments were performed under ambient temperature (22 ^oC) and with a flow rate of 300 lh^{-1}. Two different volume concentrations were tested: 0.05 % and 0.5%.

Typical FBRM and PDA results for both volume concentrations are shown in Fig. 2, where the chord length distribution (C, FBRM results) is presented in the inlet and outlet regions of both valves. A comparison of the median and the mean values of the distributions presented in Fig. 2 are further shown in Table 1. For the lower concentration, the gate valve reduces the inlet median particle value by a factor of 1.8 whereas the cyclonic valve maximizes this number by a factor of 1.2. For the higher concentration, the mean value at the cyclonic valve outlet is increased by a factor of 1.4. These results indicate that the cyclonic valve should reduce the residence time of the flow mixture inside gravimetric separators by a factor of 2. The PDA results offer the same conclusion. Average diameters in the outlet of the cyclonic valve are 70% higher than the diameters observed in the outlet of the choke (gate) valve.

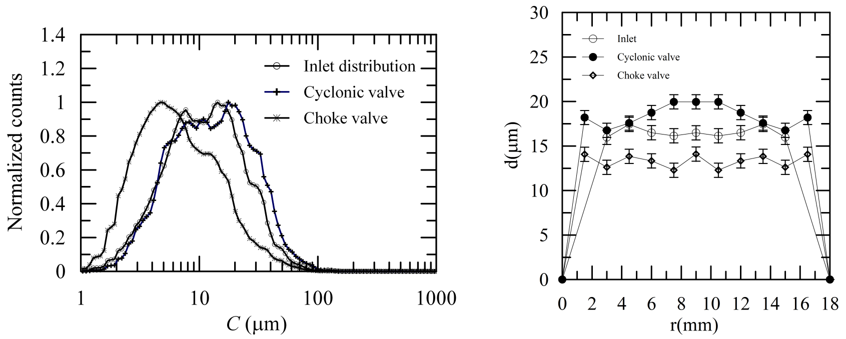

Figure 2. Mean diameter distribution in the inlet and outlet of the cyclonic valve in comparison to the outlet of the choke valve. Tests were performed with 0.05% and 0.5% of oil in water. FBRM results: left, PDA results: rigth.

Table 1. Summary of the oil dropletsize in the outlet.
Test condition: 0.05 % oil/water.

	Inlet
Median (μm)	11.45
Mean (μm)	42.61
	Choke valve
Median (μm)	6.27
Mean (μm)	39.05
	Cyclonic valve
Median (μm)	13.57
Mean (μm)	46.20

VELOCITY FIELD IN THE CYCLONE

The flow in a hydrocyclone is very complex (Marins et al 2010). Regions of large turbulence and shear forces can be observed predominantly in the inlet and in the outlet. These features, of course, promote droplet break up, but are counteracted by the action of the centrifugal forces. The typical behaviour of the tangential and axial mean velocity components, V_θ and V_z, in the cyclonic valve is shown in Figure 3. Early studies have divided the tangential profile in two parts: an inner part that closely resembles the rotation of a rigid body and an outer part that behaves like a free vortice with $V_\theta r^n$ = constant. Here, the same trend has been observed.

The axial mean velocity in a hydrocyclone nearly follows a Gaussian profile, it is negative close to the wall and positive in the center (Marins et al., 2010). The velocity profiles in Figure 3 are quite different from those shown in Marins et al. (2010). Since in a cyclonic valve all flow is directed to a single outlet, two velocity peaks are observed close to the wall, with a plateau of nearly zero velocity ($\approx$ 0.25 ms^{-1}) in the neighborhood of the origin. Profiles for the axial mean velocity were measured in four different positions.

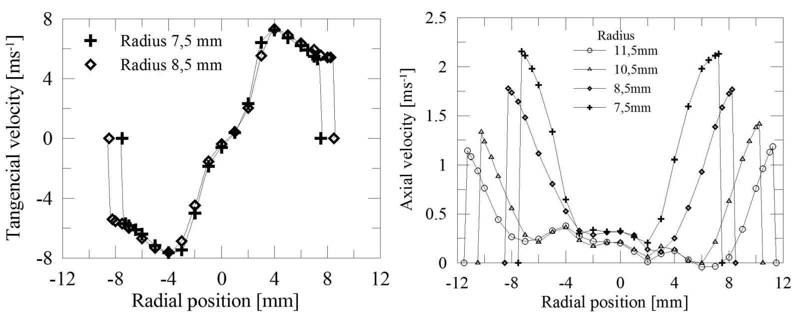

Figure 3. Mean tangential(left) and axial velocity profiles(right) in the cone region of the cyclonic valve.

References

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