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NEW CONCEPT FOR A LIQUID-LIQUID CYCLONIC VALVE

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Abstract. Smart choke valves are the future trend in the oil industry. In addition to their classical role in the control of intermittent flow, these valves have the huge benefit of easing phase separation. Smart valves should also preferably be a new generation equipment that could be used in different flow conditions (pressure, flow rates, component fraction). The present work introduces a new geometry to cyclonic valves, so as to make the energy dissipation rate more distributed and the centrifugal effects enhanced. The performance of the new valve is analyzed and compared with a regular globe valve. The new geometry exhibits a promising performance.

Keywords: Cyclonic valve, smart valve, two-phase flow, emulsion, coalescence.

1. INTRODUCTION

Any separation process based on gravity is prone to require large volume facilities. In addition to the evident industrial organization problems and the costs that large areas, volumes and weights demand, gravitational processes have a disadvantage related to the separation efficiency: the gravitational acceleration is constant.

One of the most efficient ways to reduce the volume of primary separation equipments (liquid/liquid or liquid/gas) consists in creating a rotation effect in cylindrical or conic equipments. The induced vortical motion allows the higher density fluid to flow through the external portion of the cyclone. Equivalently, the fluid with the lower density is forced to remain in the core of the equipment. For some cases, any induced large turbulent kinetic energy dissipation and high shear rates (due to the mechanical design of the project and the resulting flow) produce detrimental effects in the separation: the formation of a very fine emulsion.
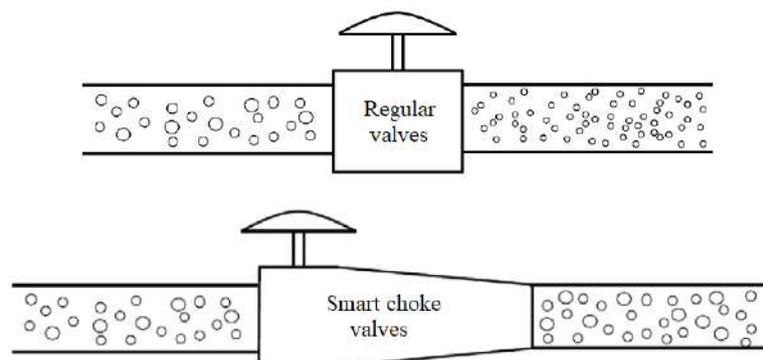

Figure 1. Performance illustration of regular and cyclonic valves. The traditional valves break up the dispersed phase due to turbulent field effects. Cyclonic valves have a better turbulence distribution, reducing the breakup rate. The centrifugal motion allows coalescence.

Cyclonic valves are devices based on two simple requirements: (i) the valve must control strong intermittent flow, and (ii) improve the phase separation process. There are several working features in the design of cyclonic valves. A recurrent practice uses small orifices to guide the flow tangentially so as to generate rotation. These orifices are the responsible to determine the desired pressure losses. The rotational motion induces drop agglomeration in regions near the pipe symmetry axis (or in the perimeter, depending on the involved densities). The proximity and impact of droplets results in coalescence. Thus, two advantages result on creating a rotational motion in the valve: (i) lower shearing effects and (ii) higher drop concentration in the center or circumferential regions of the flow, resulting in coalescence. Fig. 1 illustrates the centrifugal effect in cyclonic valves compared to a regular valve used in industry.

In this work, the behavior of a oil-water emulsion through a regular globe valve and a new cyclonic valve is analyzed experimentally.

2. NUMERICAL SIMULATION FOR THE NEW CYCLONIC VALVE

A numerical simulation using computational fluid dynamics (CFD) was developed to evaluate the location of concentrated pressure losses for water flow in the new cyclonic valve. These concentrated pressure loss regions must be avoided owing to the fact that high turbulence kinetic energy dissipation levels induce drop breakup. Fig. 2a shows the pressure distribution through the valve. The streamlines of the flow are also presented. High pressure drop regions appear at the end of the ramp and at the start of the conical region. Turbulent kinetic energy dissipation values are presented in Fig. 2b, the presence of high dissipation zones is evident. These zones were perfected so as to create a new design with less detrimental effects.

The centrifugal effects increase the velocity gradient in the very small regions that present complex geometry. For this reason, any assessment of the local velocity fields of the flow is very difficult, as mentioned by Marins *et al.* (2009). The model used in the numerical simulation was the Shear Stress Transport Model (SST), described in the works of Menter and Esch (2001), Menter *et al.* (2003) and Hellsten (1998). This model applies the $\kappa - \epsilon$ model for regions far away from the wall, and $\kappa - \omega$ near the wall. The solver pimple-Foam (that allows the simulation of single-phase, isothermal and incompressible turbulent flows) and a 2-million element mesh were used in the simulation.
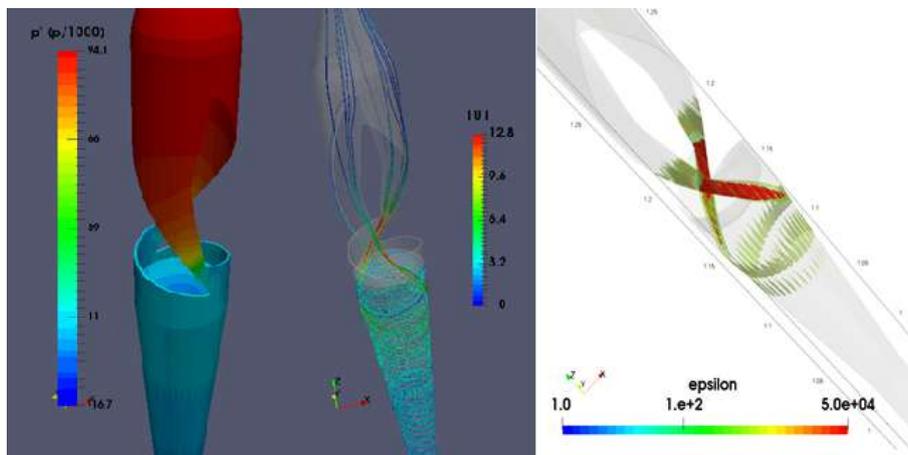

Figure 2. a) Simulation of pressure distribution (left). b) Turbulent kinetic energy dissipation in $m^2 s^{-3}$(right).

The proposed design of cyclonic valve is shown in Fig. 3. The shape is completely different from any commercial valve and the design concept was based on improving the performance of the cyclonic valves available in the industry. The geometry is divided in three parts, joined by flanges, allowing an easier modification and improvement of the individual pieces.

3. EXPERIMENTAL PROCEDURE

The experimental setup consists of a 3.0 m long open circuit. Two 1" diameter pipes were set in parallel to test each valve. A 70 liter reservoir, especially designed in this experiment, was used to prepare the emulsions. The emulsions were moved through a progressive cavity pump (PCP) with a nominal flow rate of 3 $m^3 h^{-1}$. This pump was so select as to reduce the break-up effects in the emulsion formation.

To measure the flow rate, a positive displacement flow meter was used. In particular, the flow meter installed in the pipe was able to measure fluids with dynamic viscosities of the order of 0.15 $Pa.s$. Two calibrated absolute pressure manometers were used to measure pressures between 0 and 10 bar in both pipes. The manometers were used to get information about the pressure in locations upstream and downstream the valves. A view of the experimental apparatus is shown in Fig. 4.
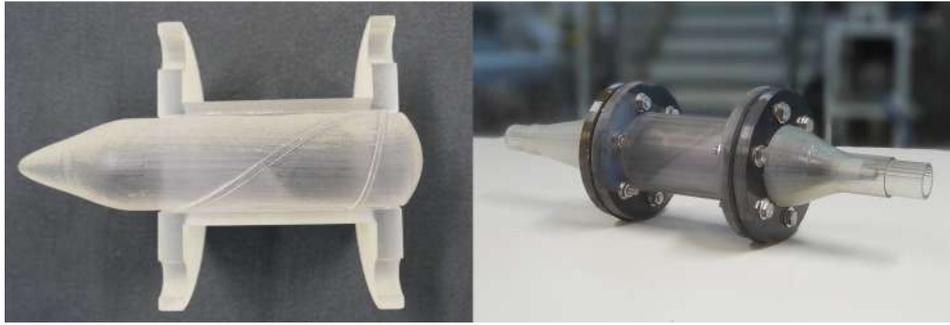
Figure 3. a) (Left) Cyclonic valve (cross section showing the internal directional ramps). b) (Right) Final version of the valve.

Figure 4. Experimental setup.

Two different oils were used to prepare the emulsions. A mineral oil with viscosity of 0.0134 $Pa.s$ at 20 $^{\circ}C$ was used in the first phase of the work. A surfactant (Tween 80) was used to establish a stable emulsion, so as to characterize the fluid without any non-expected phase separation.

In a second phase of the work, the Atlanta field oil with viscosity of 119 $Pa.s$ at 20 $^{\circ}C$ was used to create a new emulsion. In this case, the presence of natural surfactants deemed an stable emulsion without the addition of any other substance.

The rheology of the fluids and the emulsions was assessed in a rotational rheometer HAAKE MARS II of Thermo Scientic industries.

Emulsions with concentrations of 500 and 1500 ppm of o/w, were tried in both valves for both oils. Two Insitec equipments were used in-line to measure the drop size distribution upstream and downstream the valve. The Insitec equipment (Fig. 5a) uses a diffraction laser technique to get a very quick drop size measurement. The measure system is controlled by the RTSizer software of Malvern that provides information about any parameter of pattern size, such as Dv10, Dv50, Dv90 and Dv[4,3]. Insitec measurements are limited to concentrations of 3000 ppm.

Emulsions with oil volumetric concentrations of 1% and 5% were analyzed using the Master Sizer equipment, Fig. 5b. Master Sizer equipment uses the diffraction laser technique in measures off-line. Information about drop size distribution is provided at the end of the measurements.

Figure 5. a) Insitec (left). b) Master Sizer (right).

4. RESULTS

Experiments for Atlanta o/w emulsions were carried out for concentrations of 1 and 5% for Reynolds numbers close to 5500 and 13500, for the globe valve and the new cyclonic valve. The drop size distribution upstream and downstream the valves were measured for each experiment.

Figure 6a shows the results for the globe valve. The drop breakup generated by the pressure drop is evident. In this case, D43 is reduced from 46.8 μm to 25.4 μm. The results for the same concentration and very close Reynolds numbers for the cyclonic valve are shown in Fig. 6b. In this case, the effects of coalescence can be identify easily. The value of D43 changes from 32.4 μm to 38.1 μm. These values represent an increase of 18% in the drop size, differently from the globe valve results that show a decrease of 46%.

The new cyclonic valve performance was consistent for all the tests, showing a consistent increase in D43 values. The experiments confirm the appropriateness of valve geometry, resulting in a substantive coalescence of drops, with an increase in D43 between 5 and 26%.
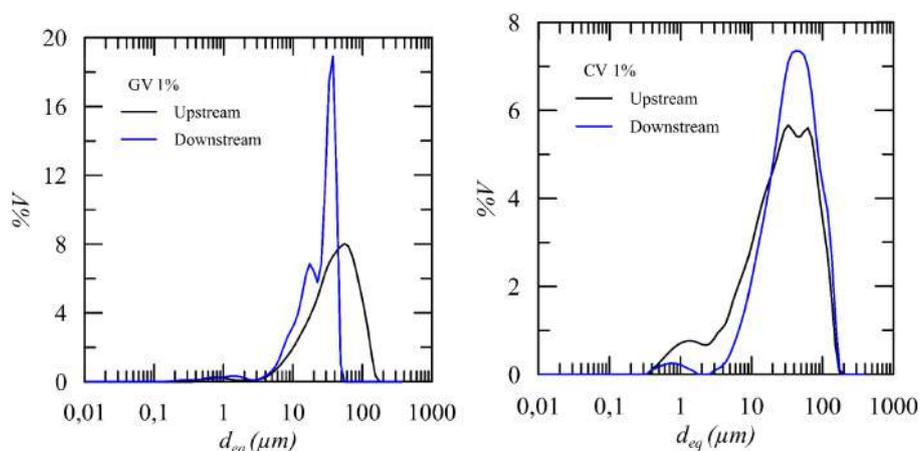

Figure 6. Drop size distribution for a 1% Atlanta oil in water emulsion, Re=5500, a) Glove Valve (left). b) Cyclonic Valve (right).

A rigorous set of data was obtained from the experiments. These data provide the necessary information to assess the performance of the designed valves.

5. ACKNOWLEDGEMENTS

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