Predicting the Two-Phase Gas/Liquid Spray Break-up Mechanism by the Dimensionless Numbers

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Abstract

Introduction

Two-phase gas/liquid atomization is a common technique used in the cracking process of bitumen in order to produce lighter hydrocarbons that can be refined under current technologies. One of the drawbacks of this spray characteristic is the inherent pulsations present both in the feeding conduit and the spray itself, which results in a poorly atomized flow that undermines the efficiency of the conversion process. It is of utmost importance to properly describe and predict spray characteristics such as d_d and flow pattern to assure that the parameters are well suited for an appropriate mixing process. The use of proven laser diagnostics, such as PDPA (Phase Doppler Particle Analyzer), combined with an impulse probe allows the experimental estimation of the droplet size and spray momentum which combined with other physical parameters like β, P_m, ρ_r and α were used to study the importance of the different dimensionless coefficients involved in the *TPGL* (Two-Phase Gas Liquid) spray formation.

Materials and Methods

To study the characteristics of a two phase gas/liquid atomization, a small scale nozzle facility was used. The nozzle was scaled at a dimension equal to one-quarter of a patented full-scale design (US Patent #: 6003789) utilized in the coker unit for the heavy oil upgrading process. A nozzle assembly, with lengths of 36.80 cm and a nozzle ID of 6.35 mm (Figure 1), was used upstream of the nozzle section. This section was used as the mixing chamber. The D_n was equal to 3.10 mm. The gas used in the experiments (air) was supplied from a standard compressor unit, while a reciprocating pump was used to create a recirculating current from the liquid (water) collector tank to the mixer section, located before the conduit. To measure the mean drop size, a 2D-PDPA was the chosen technique. The measurements were taken at different radial positions measured from the nozzle centerline which varied from -30 mm to +30 mm. The working principle of the PDPA unit was found in literature [1-4].

Results and Discussion

The effects of changing the air to liquid mass ratio on the droplet diameter and slip velocity showed that at the centerline, the velocity value is independent of β for all cases studied. At 15% β, the slip value collapses with all the other cases. For points beyond 0.5 r/R, the slip velocity becomes negligible. The results obtained for the *Oh* proved that the viscosity effects are negligible when compared to the surface tension effects. The effects of the gas-to-liquid ratio on U_r and We_{crit} yield that the droplet break-up process occurs at $We_{crit} = 12$ independently of the value of β. The effects of *Oh*, *Eo*, *St*, We_g are not important when compared to other dimensionless numbers, like the Fr_g and *Ga* (Figure 2). The results obtained show that the gas phase velocity has an essential role in the break-up mechanism of the droplets while the mixing pressure is less important for the atomization process.

Nomenclature

d	droplet size
D	diameter
Eo	Eotvos number
Fr	Froude number
Ga	Galileo number
Oh	Ohnesorge number
L	length
r	radial distance

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R	radius
Re	Reynolds number
St	Strouhal number
U	Axial velocity
We	Weber number
α	void fraction
β	gas to liquid mass ratio
ρ	density

Subscripts

crit	critical
d	droplet
g	gas
l	liquid
m	mixer
n	nozzle
r	ratio

References

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[4] Gréhan, G., Gouesbet, G., Naqwi, A. and F., D. *Part. Syst. Charact.* 11: 133-144, (1994).

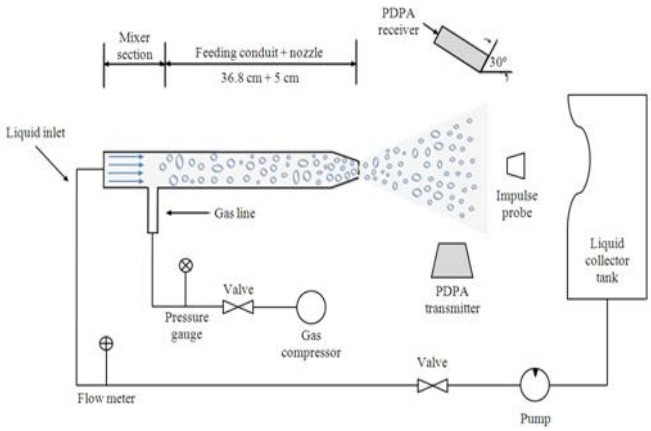

Figure 1. Schematic of the experimental set-up (not to scale). The length (L) and internal diameter of the feeding conduit (D_c) is 36.8 cm and 6.35 mm. Tip of the nozzle is 3.10 mm (D_n).

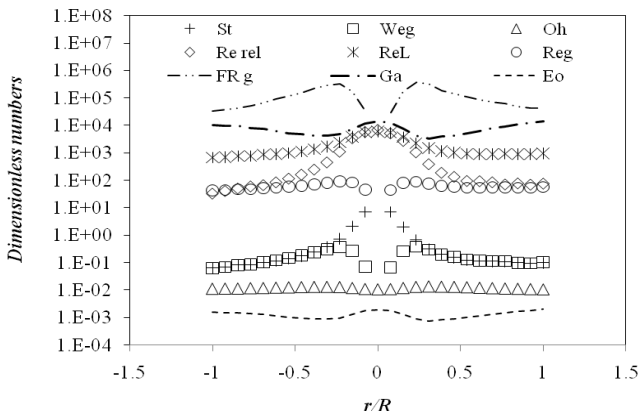

Figure 2. Effects various dimensionless numbers of the spray beak-up mechanism at 2% gas to liquid mass ratio.