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Garcia, Matheus M.; Portela, Luis M.

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Swirl Effects on Gas-Liquid Upward Vertical Pipe Flow

Matheus M. Garcia[1], Luis M. Portela[1*]
[1] Department of Chemical Engineering, Delft University of Technology, Delft, Netherlands
*Corresponding author: l.portela@tudelft.nl

Introduction

The flow patterns of gas-liquid flows in vertical pipes were extensively studied in the past [1]. Recently, research has focused on gas-liquid swirl flow [2] due to their importance in, e.g., industrial separation processes. The visualization deals with the flow in an inline swirl separator, both upstream and downstream of the swirl element, to understand (i) the swirl effects on the flow patterns, and (ii) the connection between the non-swirling patterns upstream and the swirling patterns downstream.

Description of the flow visualization method

In the inline swirl separator the swirl is imposed by a swirl element with fixed vanes angled in relation to the original flow direction (fig. 1a). Two synchronized high-speed cameras were used to record: (i) the flow across the swirl element, capturing the transition between the non-swirl (upstream) and swirl (downstream) patterns, and (ii) a larger view of the swirling flow downstream, with a better representation of the swirl flow patterns (fig. 1b). Details of the setup can be found in [3].

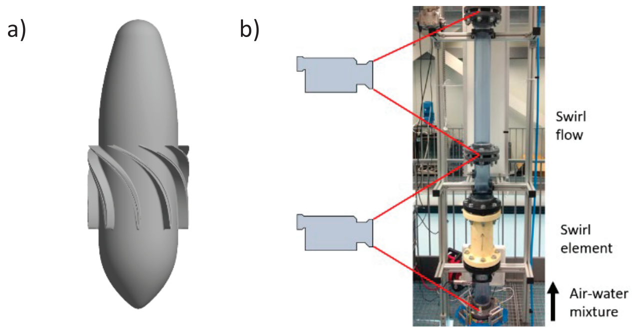

Figure 1: a) Swirl element. b) Locations of the inline swirl separator recorded by the high-speed cameras

Physical insight and conclusions

Five combinations of air-water flow rates are presented in the video, illustrating all the swirling flow patterns that were observed in the experiments, done over a wide a range of flow rates (fig. 2).

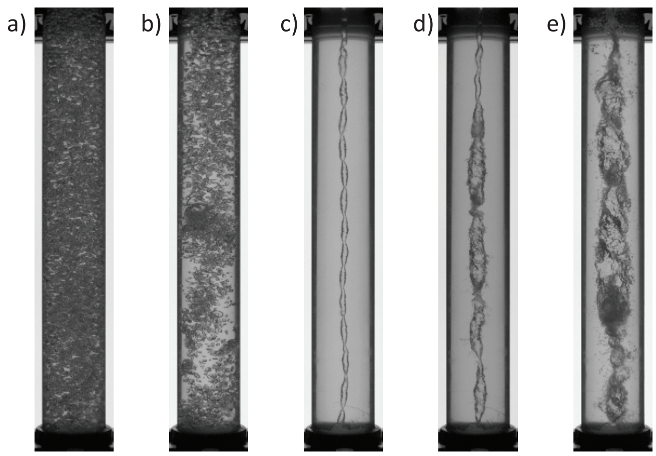

Figure 2: Gas-liquid swirl flow patterns. a) weak swirling bubbly, b) swirling bubbly with bubble agglomeration, c) stable column, d) pulsating column and e) unstable column.

The swirl element links the liquid flow rate to the angular momentum of the flow, and, therefore, to the centrifugal force that pushes the gas towards the pipe centerline. For sufficiently high liquid flow rates a core of gas is formed downstream of the swirl element. The stability of the gas core is reduced with the increase in the gas flow rate. The effect is associated with changes in the flow pattern upstream the swirl element that propagate to the swirling region downstream: (i) for bubbly flow upstream, large bubbles are converted into pulses in the gas core; (ii) for slug flow upstream, Taylor bubbles are converted into sudden enlargements of the gas core, being often followed by its collapse. The video ends with the swirl flow pattern map for a wide range of liquid and gas superficial velocities.

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