Particle Image Validation of a Classifier Hydrodynamic Model

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Abstract

The aim of the project documented here is to study the hydrodynamic behaviours observed in an alumina hydrate classifier. The flow pattern in a classifier influences the sedimentation: large particles (~ 100 µm) fall towards the underflow under the effect of gravity, while fine particles (~ 10 µm) are transported by upward flows and are evacuated at the overflow. An efficient classifier allows for an appropriate particle segregation based on targeted sizes at the overflow and underflow. In this project the flow pattern is described by a mathematical model of turbulence with a free surface that is calculated by finite elements using the ANSYS FLUENT software. The free surface represents the air / water interface of the overflow through the two-phase model VOF (volume of fluid). Many turbulence models may be found in the literature. To select the most appropriate one, an experimental validation is conducted by particle image velocimetry (PIV), where a thin slice of the classifier tank is illuminated (laser tomography) and the velocity field is measured with a high-resolution digital camera. This study is carried out in a 48.3 cm diameter pilot classifier and maps of the fluid velocity field by measuring the velocity of fine tracer particles representative of the fluid flow. The velocity field favors the k-epsilon turbulence model which provides, along with the free surface, an accurate representation of the velocity field in the classifier.

Keywords: Classifier hydrodynamic modeling; turbulence models; alumina hydrate classifier; Particle-size distribution (PSD); ANSYS FLUENT.

1. Introduction

In the Bayer process, classifiers are used to sort precipitated alumina hydrate according to its particle sizes. Most of the larger particles (80 µm to 140 µm) settle to the bottom of the tank while most of the finer particles (1 µm to 80 µm) are carried by the upward liquor flows to the overflow, where they are removed [1] [2] [3]. Ideally the overflow liquor should only contain solid particles of the targeted sizes, but some other particles may still remain in this overflow. The sorting performance of classifiers depends on the material physical properties and on their geometrical configurations and operational mode. Having a relatively simple way of assessing the efficiency of classifiers would be very useful.

This paper presents a mathematical model which numerically simulates the hydrodynamic behavior of a classifier, and with which its sorting efficiency could be evaluated. The calculated flow pattern is validated by comparing it to that measured in a pilot classifier by particle image velocimetry (PIV) and by comparing the calculated and measured overflow thicknesses.

2. Experimental Set-up

The tank of the pilot classifier consists of five cylindrical Plexiglas sections having a diameter of 48.3 cm and a combined height of 1.057 m. Plexiglas is used because of its transparency, which is required for the PIV tomography measurements. At the top of the tank a gutter collects the overflow. An underflow pipe 4 cm in diameter is at the apex of a 30° conical steel bottom. A black plastic tube 16.4 cm in diameter and 13.5 cm high is used for the feed well. The black color is chosen to minimize the reflection of the PIV laser light in the upper section. This reflection would interfere with the PIV measurements. A feed pipe 9 mm in diameter is inserted in the upper middle of the feed well. The mouth of the feed pipe is located 8.1 cm above the bottom of the feed well. A horizontal circular deflection plate having a diameter of 5.1 cm is centered 1.9 cm under the feed pipe. The fluid velocity fields in zones A, B, C, D and E of the tank are monitored (Figure 1) at four feed flow rates such that the residence times of the pilot are representative of those encountered with industrial classifiers.

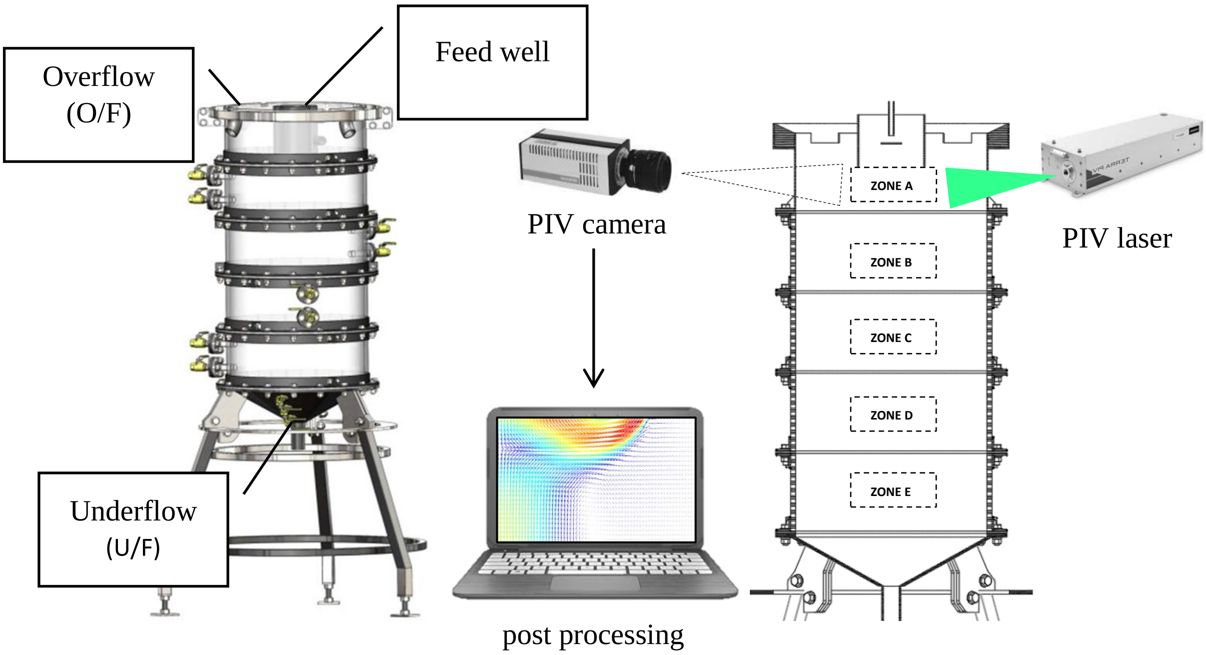

Figure 1. Experimental set-up

A technique of PIV by tomography is used for monitoring the velocity fields in the tank. A laser with a pulse duration ranging from 10 to 100 µs and with a frequency of 1 to10 kHz illuminates different areas of the classifier. A high resolution digital camera (1 000 pix X 1 000 pix) with an acquisition frequency ranging from 0.5 to 5 kHz films the position of the particles. The displacement of a particle, and hence its velocity, is measured by comparing a pair of images filmed at an interval of ten microseconds. The particle shapes are used by the Flow Manager post processing software to identify the same particle in a pair of images and evaluate its velocity (Figure 2) [4]. This software scans all pairs of recognized particles in 32 pix X 32 pix interrogation zones and calculates their velocities. Abnormal velocities are rejected and the remaining data is smoothed to obtain a representative velocity field as a function of time. A complete PIV scan lasts 10 seconds.

Alumina particles having a diameter of 3 µm and a density of 2.4 g/cm³ were injected into the feed well as the PIV tracer. Alumina is a good choice as a tracer because it reflects light rapidly with a response time of the order of 0.9 µs.The tracer must be carried by the fluid to be representative of the flow pattern. The settling velocity of the particles, if large enough, could make them unsuited as a tracer by adding their downward speed to the measured flow velocity.

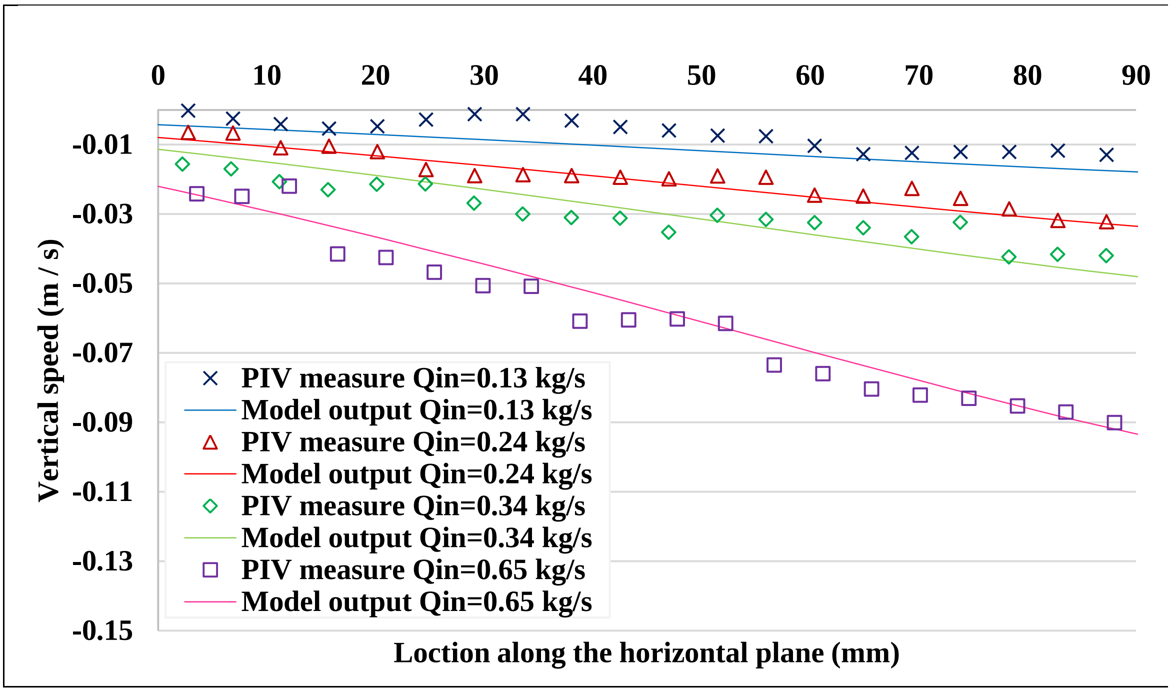

Figure 10. Vertical speed in zone E for various inflow rates.

5. Conclusion

The VOF model, coupled with the k-ε turbulence model, simulates well the hydrodynamic behavior in a hydrate classifier for different feed rates. The validation of the model was accomplished by comparison with PIV velocity and overflow thickness measurements. In a future study, the k-ε turbulence model could be coupled with the Euler-Euler multiphase model to calculate the solid concentrations and granulometries exiting a classifier at its underflow and overflow as a function of the feed solid granulometries and operating conditions. In this way the sorting performance of a classifier could be evaluated. An application of such a numerical tool would be to evaluate beforehand the outcome of any suggested modification to the structural configuration or operational conditions of a classifier

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