Separation and Purification Technology 161 (2016) 121–128

Contents lists available at ScienceDirect

Separation and Purification Technology

journal homepage: www.elsevier.com/locate/seppur

Dissolved gas separation using the pressure drop and centrifugal characteristics of an inner cone hydrocyclone

Xiao Xu [a], Qiang Yang [b,*], Chao-yang Wang [a], Xiao-ling Ge [a], Hua-lin Wang [b]

[a] Key Laboratory of Pressure Systems and Safety, Ministry of Education, East China University of Science and Technology, Shanghai 200237, China
[b] State Key Laboratory of Chemical Engineering, East China University of Science and Technology, Shanghai 200237, China

ARTICLE INFO

Article history:
Received 22 September 2015
Received in revised form 4 January 2016
Accepted 5 January 2016
Available online 6 January 2016

Keywords:
Dissolved gas separation
Turbulence flow
Inner cone hydrocyclone

ABSTRACT

Although compact separation by a hydrocyclone is popular in the chemical and petro-chemical industry, the separation of dissolved gas from continuous liquid in a hydrocyclone is rarely mentioned, and few investigations consider the gas solubility changes occurring with the cyclone flow. This work investigates dissolved carbon dioxide separation from water by an inner cone hydrocyclone. When the inlet mass flow is less than 1.2 m^3/h, increasing the inlet mass flow could increase the separation efficiency. When the inlet mass flow is more than 1.2 m^3/h, increasing the inlet mass flow will decrease the separation efficiency. An optimum inlet mass flow of 1.2 m^3/h can provide the maximum separation efficiency of 40.2%. Turbulence simulations also assist in analyzing the flow pattern and the separation progress.

1. Introduction

The hydrocyclone, as a compact separator with a high separation efficiency, is gradually replacing the conventional vessel separator in the petroleum industry [1–4]. It is commonly used for the degassing of extracted oil in offshore oilfields, the separation of reaction products and hydrogen in petroleum hydrogenation, and the removal of light hydrocarbons from a rich amine solution. Cylinder separation is a simple and compact method of liquid–gas separation based on centrifugal separation [5]. The inlet can be designed as a tangential inlet or an axial inlet, which can lead to differences in separation performance [6]. The tangential inlet is typically set in a T-junction liquid–gas separator [7–9]. The inner cone hydrocyclone has the advantages of a small pressure drop and high liquid–gas separation efficiency [10].

The liquid–gas flow in a hydrocyclone is a complex progress that has attracted much attention. The centrifugal force in an inner cone hydrocyclone is the principal separation factor in deaeration, at the cost of some flow pressure [11]. Different types and dimensions of hydrocyclone will lead to different centrifugal forces and pressure drops. The tangential velocity and pressure distribution of the hydrocyclone have been studied in previous works in the literature, and the results indicate a strong centrifugal effect and drastic pressure changes in the hydrocyclone [12]. However, liquid–gas separation operates on the assumption that the liquid and gas are immiscible. Investigation of the chemical engineering flow shows that gas dissolved in liquid can result in a significant affect and cannot be neglected [13]. As we all know, the flow pattern has an important influence on gas saturation solubility in liquid [14]. Additionally, the dissolved gas content in liquid is closely related to the flow pattern. Based on the characteristics of the hydrocyclone and of gas dissolved in liquid, this paper proposes the separation of dissolved gas from liquid using the inner cone hydrocyclone.

An inner cone hydrocyclone consists of a cylinder with two inner cones inside the cylinder. The flow is injected tangentially through the inlet opening in the middle of the cylinder, and a strong swirling motion is developed within the inner cone hydrocyclone. Deaerated liquid escapes the hydrocyclone through two tangential liquid-outlets, and gas exits through two axial gas-outlets. Fig. 1 shows the fluid flow in an inner cone hydrocyclone. The decrease in pressure in the radial direction accelerates dissolved gas desorption, and bubbles will form. The centrifugal forces then carry the bubbles toward the center. Dense fluid moves close to the wall, and the bubbles move along the center line.

Dissolved gas separation refers to a large-scale range. Dissolved gas molecules exit homogeneously from liquid, where the interface scale can be seen as 10^{-10} m. After the formation of the critical size of nuclei, bubbles arise that commonly have sizes on the micrometer level [15]. Bubbles are separated by the centrifugal forces and contribute to the formation of the air core. The air core size in a

---

* Corresponding author at: State Key Laboratory of Chemical Engineering, East China University of Science and Technology, 130 Meilong Road, Shanghai 200237, China.

E-mail address: qyang@ecust.edu.cn (Q. Yang).

http://dx.doi.org/10.1016/j.seppur.2016.01.006
1383-5866/

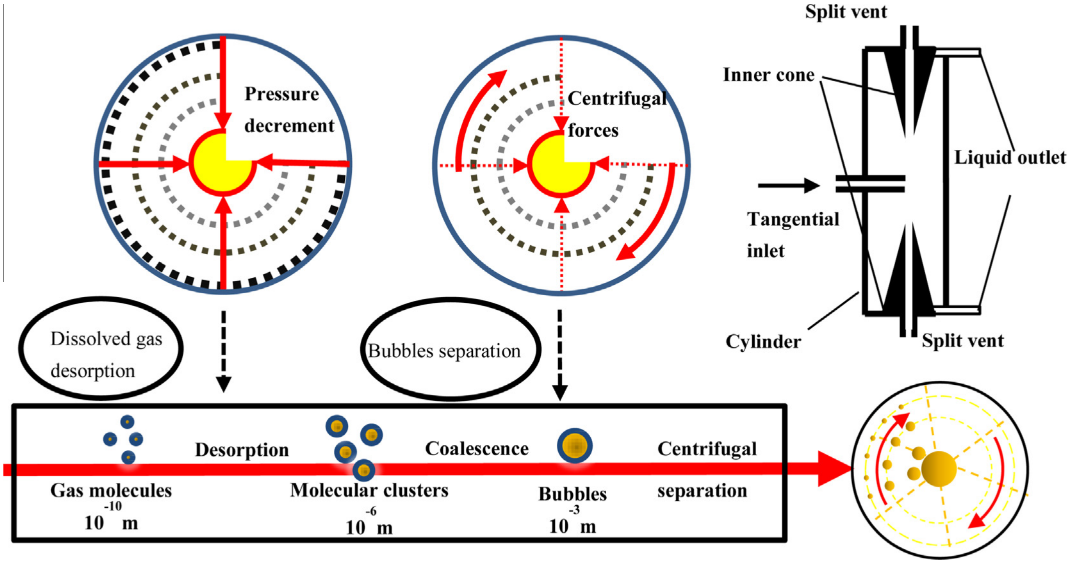

Fig. 1. Schematic diagram of dissolved gas separation by inner cone hydrocyclone.

hydrocyclone has been previously reported at approximately the millimeter level [16].

2. Hydrocyclone design

The feed method of the hydrocyclone is one of its important design features. A single tangential inlet is most common but offers few advantages, so a dual inlet has been developed for liquid–gas separation [17]. The inner cone hydrocyclone has two symmetrical rectangular inlets, and a circular pipe is attached to the rectangular inlets. The cylinder diameter of the hydrocyclone is 50 mm, and the inner cone height is 60 mm. Two axial split vents are set at the inner cone flanges. The geometry of the hydrocyclone is shown in Fig. 2.

3. Performance characteristics

For the inner cone hydrocyclone liquid–gas separator, the overall separation efficiency can be expressed as follows:

$$E = (1 - g_{outlet}/g_{inlet}) \times 100\% \qquad (1)$$

where g_{outlet} and g_{inlet} are the contents of carbon dioxide at the liquid outlet and in the feed, respectively.

The flow split ratio of the hydrocyclone is defined as the ratio of the liquid mass flow at the split vent to the flow at the feed. The split ratio describes the liquid quantity entrained by gas, and a lower split ratio indicates less liquid waste in the degassing process.

$$R = \frac{L_{outlet}}{L_{inlet}} \times 100\% \qquad (2)$$

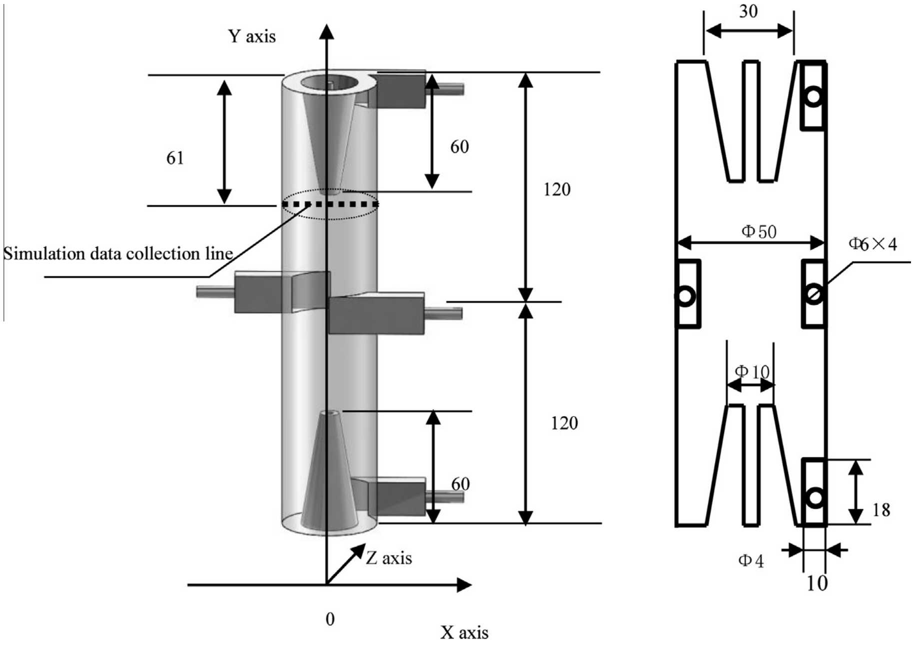

Fig. 2. Geometry of inner cone hydrocyclone.