Separation and Purification Technology 206 (2018) 268–285

Contents lists available at ScienceDirect

Separation and Purification Technology

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

An overview of operating parameters and conditions in hydrocyclones for enhanced separations

Jinyi Tian[a,b], Long Ni[a,b,*], Tao Song[a,b], James Olson[c,d], Jianing Zhao[a,b]

[a] School of Architecture, Harbin Institute of Technology, Harbin, PR China
[b] Heilongjiang Cold Region Architectural Science Key Laboratory, Harbin, PR China
[c] Department of Mechanical Engineering, University of British Columbia, Vancouver, BC, Canada
[d] The Pulp and Paper Centre, University of British Columbia, Vancouver, BC, Canada

ARTICLE INFO

Keywords:
Hydrocyclone
Separation efficiency
Cut size
Energy consumption
Split ratio

ABSTRACT

Hydrocyclones are widely employed in both heavy and light industries. However, exact mechanisms underlying enhanced-separation technologies developed by optimizing operating parameters and conditions in hydrocyclones remain unclear. Accordingly, many research groups have conducted numerous investigations to expand the application range of hydrocyclones by optimizing operating parameters and conditions. This paper presents a comprehensive state-of-the-art review of the aforementioned hydrocyclone enhanced-separation technologies, which are classified into two groups: (i) operating parameters, including feed flow rate, feed pressure, feed density difference, feed particle parameters (concentration, size, shape, and arrangement), and feed fluid parameters (viscosity and rheology); and (ii) operating conditions, including electrical hydrocyclones, magnetic hydrocyclones (electromagnetic field and permanent magnetic field), magnetic fluids hydrocyclones, electrochemical hydrocyclones, flocculant-assisted hydrocyclones, hydrocyclones enhanced by flotation, hydrocyclones enhanced by control particles; hydrocyclones enhanced by adjusting back pressure, and hydrocyclones enhanced by monitoring and automatic control. These enhanced-separation technologies were analyzed and summarized based on the critical separation-performance parameters, such as separation efficiency, cut size, split ratio, energy consumption, capacity, and separation sharpness. It is hoped that both reviewed contents and proposed challenges may be helpful to the researchers and eventually yield some perspective knowledge, which results in the improvement of economic feasibility of separation by hydrocyclones.

1. Introduction

Cyclones, i.e., stationary mechanical devices using the centrifugal force to separate or classify, have been extensively applied in both heavy and light industrial applications [1–4] including gas cleaning, burning, atomizing, spraying, liquid clarification, liquid thickening, powder classification according to size, sorting according to solids density, sorting according to particle shape and density, and countercurrent washing. Generally, they are classified into two groups: (i) The cyclones particularly designed for liquids, which are referred to as hydrocyclones [3], hydraulic cyclones, dense medium cyclones, solid-liquid cyclones, liquid-solid cyclones or liquid-liquid cyclones; and (ii) the other cyclones, which are referred to as gas cyclones, cyclone separators, cyclone dust collectors, gas-liquid cyclones, solid-gas cyclones or cyclone collections. A survey of literature demonstrates that a large number of investigations dealing with cyclones have been published and cited in the last two decades (Fig. 1), presenting high potential for research, including the $PM_{2.5}$ separation [5], cell separation [6], submicron particles separation [7–13], cyanide recovery [14,15], hazardous-trace-metals (e.g., Cd, Pb, and Ni) separation [16], ions and molecules separation [17,18], flocs separation [19], flocs classification [20], fibre separation [21], fibre fractionation [22,23], chemical oxygen demand (COD) and biological oxygen demand (BOD) removal [24], insoluble slimes removal [25,26], radionuclide and volatile organic compounds (VOC) removal from soil and ground water [27], froth flotation of mineral particles and dispersed oil [28], SO_2 removal from flue gas [29], and natural gas separation [30].

Wherein, recent years, hydrocyclones have been witnessed a rising worldwide popularity owing to their irreplaceable merits in solid-liquid, gas-liquid, liquid-liquid, gas-liquid-solid, gas-liquid-liquid, and solid-liquid-liquid separation [1–3], such as small cut sizes ($\geq 2\,\mu m$ [3,31], even submicron [8,9,11]), high separation efficiency, low energy consumption, no moving parts, wide operating range, low cost, and small volume. Specifically, to date, hydrocyclones have been

* Corresponding author at: School of Architecture, Harbin Institute of Technology, Harbin, PR China.
E-mail address: nilonggn@163.com (L. Ni).

https://doi.org/10.1016/j.seppur.2018.06.015
Received 16 April 2018; Received in revised form 23 May 2018; Accepted 5 June 2018
Available online 05 June 2018
1383-5866/ © 2018 Elsevier B.V. All rights reserved.

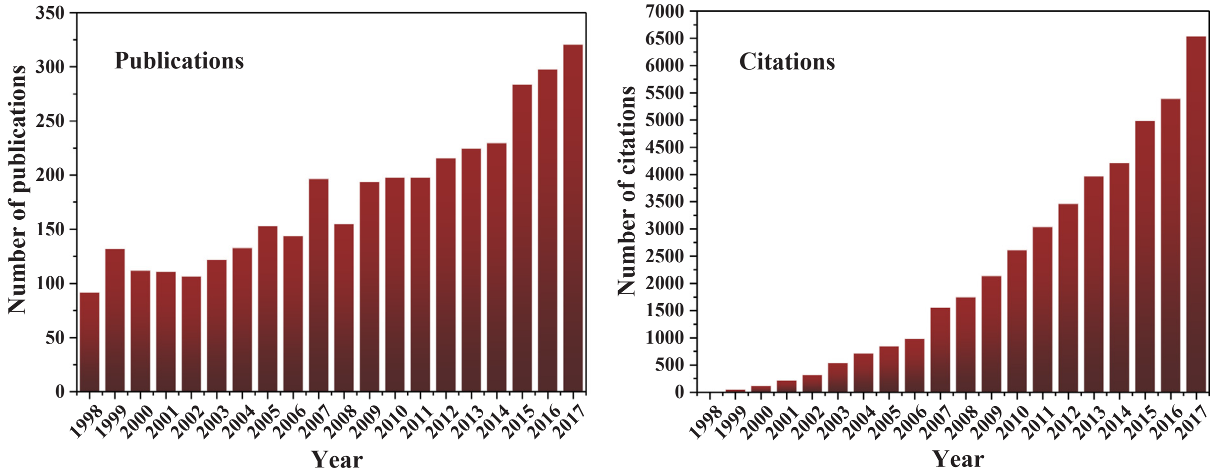

Fig. 1. Number of publications and citations related to cyclones in recent 20 years, obtained from the Web of Science Core Collection with the following keywords: hydrocyclone*, hydraulic cyclone*, dense medium cyclone*, solid-liquid cyclone*, liquid-solid cyclone*, liquid-liquid cyclone*, cyclone separator*, cyclone dust collector*, gas cyclone*, gas-solid cyclone*, solid-gas cyclone*, and cyclone collection* (Check on May 23, 2018).

widely employed in industries, such as mineral [32,33], chemical [34,35], coal [36,37], petroleum [38], papermaking [21], environmental protection [24,39], soil remediation [27,40], waste management [41,42], agriculture [43], aquaculture [44], food [45,46], biotechnology [47,48], nanotechnology [8], material science technology [49], and thermal energy [50,51]. Therefore, to optimize the separation performance and further expand the application scope of hydrocyclones, a great deal of previous research into hydrocyclones have been conducted to develop novel enhanced-separation hydrocyclone technologies.

To the best of authors' knowledge, although the first patent on the hydrocyclone is about 128 years old, to date, there are just a few reviews on hydrocyclones (Table 1), and marginal effort has been attempted to comprehensively review and summarize enhanced-separation hydrocyclone technologies developed by optimizing operating parameters and conditions. For example, Sheng [52] published a review on the separation of liquids in a conventional hydrocyclone, which mainly demonstrated the definition of the separation efficiency of a two-phase, liquid system in the presence of a solid. Chakraborti et al. [53], Svarovsky [54] and Narasimha et al. [55,56] presented reviews on hydrocyclone models. Bergström and Vomhoff [57] reviewed the experimental studies about the flow field of hydrocyclones. Holtham [58] focused on dense medium cyclones for coal washing, while Kharoua et al. [59] and Liu et al. [60] on de-oiling hydrocyclones and three-phase hydrocyclones, respectively. Wang et al. [18] presented the researches and developments of the hydrocyclonic separation technologies, including the fish-hook phenomenon, separation of molecules, ions, and their aggregates, and effect of the shear force on the particle behaviors. Tim Napier-Munn [61] introduced the past, present, and future of the dense medium cyclones. Our last review [62] on hydrocyclone technologies concentrated on the enhanced-separation technologies developed by optimizing geometric parameters, which seem to be less complex than those developed by optimizing operating parameters and conditions.

What is worse, a number of different, even contrary, results were obtained during the past years. For instance, some argued that the "fish-hook effect", that is, an inflexion in the separation efficiency curve indicating a dip at sub sieve sizes, was of physical origin [63–70], whereas others [71–77] believed that it was just random and sporadic phenomenon caused by the measurement errors. Most researchers believed that the feed pressure did not have significant effect on the separation performance of hydrocyclones, and it was not need to use high feed pressure (>150 kPa) to enhance hydrocyclone separation [44,78–81]. Nevertheless, by using a hydrocyclone operating at high feed pressure up to 6 MPa, Neesse et al. [8] realized the solids classification in submicron range, which cannot be achieved by utilizing hydrocyclones with lower feed pressure.

The aim of this review is to provide a comprehensive and state-of-the-art review of existing literatures on the enhanced-separation hydrocyclone technologies developed by optimizing operating parameters and conditions. To achieve a better understanding of these technologies, the enhanced-separation technologies are categorized into two main groups (Fig. 2): (i) operating parameters, including feed flow rate, feed pressure, feed density difference, feed particle parameters

Table 1
List of reviews relating to hydrocyclones.

Review title	Authors	Year & Ref.
Separation of liquids in a conventional hydrocyclone	H.P. Sheng	1977 [52]
Fluid flow in hydrocyclones: a critical review	N. Chakraborti, J.D. Miller	1992 [53]
A critical review of hydrocyclone models	L. Svarovsky	1996 [54]
Dense medium cyclones for coal washing - A review	P. N. Holtham	2006 [58]
A review of flow modeling for dense medium cyclones	M. Narasimha, M. S. Brennan, P. N. Holtham	2006 [55]
A review of CFD modelling for performance predictions of hydrocyclone	M. Narasimha, Matthew Brennan, P. N. Holtham	2007 [56]
Experimental hydrocyclone flow field studies	Jonas Bergström, Hannes Vomhoff	2007 [57]
Hydrocyclones for de-oiling applications - A review	N. Kharoua, L. Khezzar, Z. Nemouchi	2010 [59]
Cyclonic separation technology: Researches and developments	Hualin Wang, Yanhong Zhang, Jiangang Wang, Honglai Liu	2012 [18]
Three-phase hydrocyclone separator – A review	Yucheng Liu, Qixuan Cheng, Bo Zhang, Feng Tian	2015 [60]
The dense medium cyclone - past, present and future	Tim Napier-Munn	2018 [61]
Optimizing geometric parameters in hydrocyclones for enhanced separations: A review and perspective	Long Ni, Jinyi Tian, Tao Song, Yongson Jong, Jianing Zhao	2018 [62]

Download English Version:

https://daneshyari.com/en/article/7043596

Download Persian Version:

https://daneshyari.com/article/7043596

Daneshyari.com