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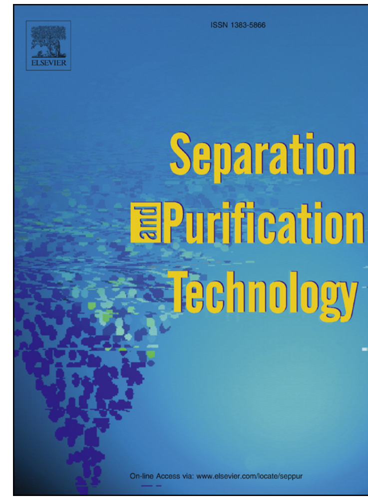

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Hydrodynamics within Flooded Hydrocyclones during Excursion in the Feed Rate: Understanding of Turndown Ratio

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Abstract

The underflow purity coefficient of a de-oiling hydrocyclone operating at a fixed split ratio is limited by the existence of a finite turndown ratio during excursion in the feed rate. The purpose of this paper is to use advanced computational fluid dynamic methods to identify a hydrodynamic reason for this phenomenon. The results of the simulation show that as the feed Reynolds number increases beyond a critical value, a redistribution of the angular momentum within the hydrocyclone decreases the distance of the zero axial gradient of radial pressure gradient, $(\mathrm{d}(\mathrm{dP}/\mathrm{dr})/\mathrm{dz})_{\mathrm{r}=0} = 0$, from the vortex finder, which thereby shortens the length of reverse flow core. The breakdown of reverse flow core at a high feed Reynolds number causes a catastrophic drop in the separation efficiency and possesses a finite turndown ratio. This insight offers guidance on how to maintain separation performance during an excursion in the feed rate.

Keywords – hydrocyclone; hydrodynamics; turndown ratio; separation; computational fluid dynamics

1. Introduction

The hydrocyclone separator was invented by Bretney in 1891 [1]. By 1970, hydrocyclones were available for thickening solid suspensions, for cleaning pulp suspensions, degassing liquids, separating immiscible liquids, and classifying solids based on size, shape and density differences (see, esp., Bradley, 1965 [2]; Svarovsky and Thew, 1992 [3]; and Rietema and Verver, 1961 [4]). During the 1970s, Thew and his team at the University of Southampton developed a class of de-oiling hydrocyclones for cleaning produced water prior to its discharge into the ocean [5, 6]. Unlike many other hydrocyclones, liquid/liquid separation hydrocyclones must operate without an air core in order to avoid the formation of an emulsion [7]. This constraint is related to the finite turndown ratio, $\max[Q_F]/\min[Q_F]$ of flooded hydrocyclones. The separation efficiency, η_o, is given by

$$0 \le \eta_o \equiv \frac{C_F - C_U}{C_F} = \begin{cases} 0, & Q_F < min[Q_F] \\ 0 < \eta_o < 1, & min[Q_F] < Q_F < max[Q_F] \\ 0, & Q_F > max[Q_F] \end{cases} \quad (1)$$

for $0 < Q_o/Q_U = \text{constant} \ll 1$

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