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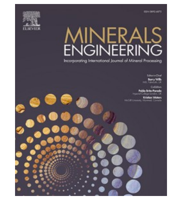

Effects of artificial impeller blade wear on bubble–particle interactions using CFD (k–ε and LES), PIV, and 3D printing

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ABSTRACT

Wear reduces velocity and turbulence by reducing the volume of impeller blades; yet there is a lack of knowledge on flotation cells. Additionally, there is a lack of knowledge in the literature regarding the effect of blade wear on bubble–particle interactions. Hence, computational fluid dynamics simulations investigated artificial impeller blade wear of a laboratory–scale Denver cell. Simulations of chalcopyrite flotation showed that blade wear increased floatability of 10 μm particles by 1.4 %, but decreased that of 180 μm particles by 3.0 %. Accordingly, it is proposed that curved surfaces due to wear increased ε (volume–averaged ε [m^2/s^3]: no–wear 20.5 and wear 25.8), increasing collision of fine particles and detachment of coarser particles. These were supported by results from large eddy simulation and particle image velocimetry measurements using three–dimensional (3D) printed impellers. Finally, experimental results from flotation experiments using 3D printed impellers and 250–300 μm methylated quartz confirmed a floatability decrease (2.1 %–3.8 %) due to wear.

1. Introduction

Flotation is a complex unit operation that separates valuable mineral particles from gangue minerals. Although there are similarities in flotation behavior between ores, there are discrepancies for various reasons, such as pulp chemistry and mineralogy (Gaudin, 1932). At laboratory and industrial scales, Denver–type flotation cells are commonly used to perform flotation. A Denver cell is a mechanically agitated tank comprising an impeller, a standpipe, a stator, and a tank. The impeller and stator generate air bubbles and mix them with the particles. Frother and collector are used to produce a consistent bubble size distribution and increase the particle hydrophobicity, respectively. Stable bubble–particle aggregates are collected from the tank top by overflow and scraping. Flotation performance (e.g., particle recovery) can be affected by reagent concentration, impeller design, tank geometry, impeller speed, aeration rate, and particle diameter (Koh and Schwarz, 2006, 2007, 2008, 2011). Kinetics and pulp potential also influence the recovery of particles. For example, 5 μm (average diameter) and medium–sized clean chalcopyrite particles can be fully recovered in the absence of a collector after grinding in a glass mill, provided that the flotation time is sufficient. The flotation time has less effect on coarser diameters (>200 μm). When redox conditions in the pulp are sufficiently reductive, chalcopyrite can be depressed, and time does not produce an increase in true flotation recovery but only entrainment (Heyes and Trahar, 1977).

Erosion or abrasion by particles in slurries causes mechanical wear on the impeller, standpipe, stator, and tank. Wear occurs in locations where high–velocity particles impinge at critical angles on the parts of an agitated tank. Impeller blades (locations of low pressure and high velocity) have been particularly investigated because their wear increases maintenance costs and power consumption; blade wear progresses with volume loss over time, resulting in blade failure (Lipsett and Bhushan, 2012; Madsen, 1988; Weetman, 1998; Wu et al., 2005). Moreover, the focus has been on blades because of their important role in (i) creating turbulence for bubble–particle interaction, (ii) the suspension of particles in the tank, (iii) the dispersion of air into bubbles, and (iv) the suction of air (Gorain et al., 2000; Wills and Finch, 2016).

Flotation in industrial rougher cells is typically performed in 20 %–40 % (w/w) slurries (Weetman, 1998; Wills and Finch, 2016; Wu et al., 2005). Particles tend to hit the lower parts of the impeller disk and the back and bottom surfaces of blades (Kee and Rielly, 2004; Weetman, 1998; Wu et al., 2010; Wu et al., 2005). Furthermore, wear is proportional to the liquid radial velocity in the impeller stream as wear ∝ velocity$^{14/5 \text{ or } 7/6}$; a similar proportion applies to wear and the impeller diameter as wear ∝ diameter$^{14/5 \text{ or } 7/6}$ (Rao et al., 1988; Weetman,

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