Understanding the Impact of Fines on Fluidised Bed Flotation: Implications for HydroFloat™ Operation on Copper Tailings

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Abstract

The HydroFloat™ fluidised-bed flotation cell was developed to overcome the poor recovery of coarse particles (>150 µm) that limit conventional mechanical flotation. However, its application to finer-than-usual feeds remains insufficiently understood, particularly regarding the influence of fines on bed stability and separation efficiency. This study investigates the effect of fines content on HydroFloat™ performance using rougher tailings from an Australian copper concentrator. The tailings were deslimed at 53 µm to produce deslimed (+53 µm) and slime (−53 µm) fractions, which were then recombined in controlled proportions to evaluate the impact of fines addition under two fluidisation water rates (2 L/min and 3 L/min). Results show that mass recovery increased monotonically with fines proportion from ~15 % at 6 % slimes to ~80 % at 67 % slimes while copper selectivity and bed stability declined. A near-linear relationship between fines input and fines recovered in the concentrate confirmed that entrainment dominates above 40 % fines, corresponding to a transition from selective to hydraulic recovery. Bed observations indicated that high fines content disrupted fluidisation, blurred the bed interface, whereas fully deslimed feeds, although visually uniform, maintained stable operation due to their narrow size distribution. These findings define a practical fines tolerance window for HydroFloat™ operation and highlight the importance of feed preparation and fluidisation control for fine tailings applications.

Keywords: HydroFloat™, fluidised-bed flotation, fines entrainment, bed stability, desliming, copper tailings

1. Introduction

The HydroFloat™ fluidised-bed flotation cell was developed to address the well-known loss of coarse particle recovery in conventional flotation (Kohmuench et al., 2001; Kohmuench et al., 2018; Ozsoy et al., 2025; Vollert, 2019; Zanin et al., 2021). Traditional mechanical and column cells float particles most efficiently in the 50–150 µm size range; beyond 150–200 µm, turbulence and buoyancy limitations cause a sharp drop in recovery (Gahona et al., 2024). The HydroFloat technology circumvents this "elephant curve" drop-off by creating a quiescent, fluidised-bed environment where coarse particles can attach to bubbles with minimal detachment (Awatey et al., 2013; Dankwah et al., 2023; Eriez, 2024; Kohmuench et al., 2018; Ozsoy et al., 2025; Vollert et al., 2019; Zanin et al., 2021). An upward flow of water fluidises the particle bed, allowing much larger particles (even approaching a few millimetres in some cases) to be recovered while maintaining good selectivity (Eriez, 2024).This advance promises significant economic benefits by floating coarse liberated grains directly; mills can reduce overgrinding, save energy, and increase throughput (Awatey et al., 2015; Concha et al., 2023;

Hassanzadeh et al., 2022; Jameson, 2010). However, fines management has become a vital aspect of successful HydroFloat operation. In practice, HydroFloat feed streams inevitably include fine particles (e.g. <100 µm) that can hinder performance if not properly managed. Excess fines in the feed can cause several adverse effects on the process. Fine hydrophilic gangue might report to the concentrate through hydraulic carry-over (entrainment) via the fluidisation water overflow, thereby lowering the concentrate grade (Vollert, 2019). High levels of fines can modify the fluidisation hydrodynamics. For example, a substantial influx of fine solids can increase the resistance of the bed to flow, potentially leading to channelling or unstable operation if water rates are not adjusted accordingly (Vollert, 2019). For these reasons, most HydroFloat implementations incorporate upstream classification to remove or reduce the fine fraction before the coarse flotation stage. Industrial trials have reinforced this approach, as efficient classification of feed or tailings has been found to be crucial for the success of the HydroFloat circuit in plant-scale studies (Eriez, 2024; Vollert, 2019; Wasmund, 2014).

The aim of the present study is to explore how the fluidised bed changes as slimes (<53 µm) are present in the system, and if there is a "tolerable" amount of fines in the feed before the fluidised bed performance declines. By optimising operational parameters such as water flow rate, fluidisation velocity, and top-bottom particle size, it may be possible to mitigate these negative effects and improve the flotation performance.

2. Materials and Methods

2.1 Ore

A 200 kg bulk sample of flotation tailings was collected from the tailings hopper of an Australian copper concentrator. The material was sourced immediately after the rougher flotation stage, which is designed to recover the majority of copper from the ore. The tailings were subsequently deslimed at 53 µm, producing two size fractions: a fine fraction (−53 µm) with a P80 of 20 µm, here after referred to as slimes or fines, and a coarse fraction (≥53 µm) with a P80 of 175 µm, hereafter referred to as deslimed. The bulk sample has been characterised chemically by inductively coupled plasma mass spectrometry (ICP-MS) (Table 1) and mineralogically by quantitative evaluation of minerals by scanning electron microscopy (QEMSCAN) (Fig. 2).

Table 1. Chemical composition of deslimed products by ICP-MS (Dadzie et al., 2025).

Elements	Composition (%)	
	Deslimed product (HydroFloat™ feed)	Slime
Al	3.4	4.1
Ca	0.53	0.57
Cu	0.15	0.11
Fe	18.7	33.0
Mg	0.8	1.2
P	0.08	0.08

Si	27.9	19.1
S	0.10	0.10

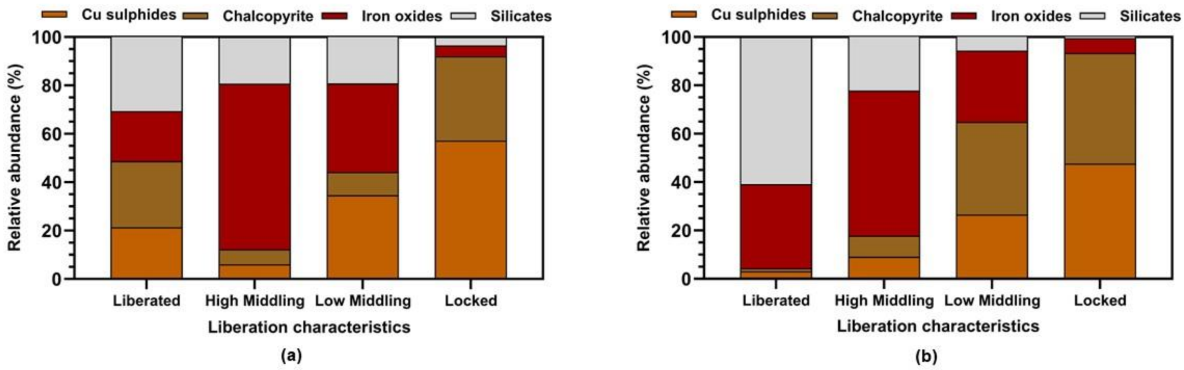

Fig. 2. Mineral liberation characteristics in (a) slime and (b) deslimed tailing samples replotted from (Dadzie et al., 2025).

2.2 HydroFloat™ Flotation Procedure

HydroFloat™ flotation (HF) experiments were conducted using a pilot-scale HF-140 unit. Each test involved approximately 15 kg of rougher tailings material constituted known proportions of deslimed and slime content (Fig.2). The feed material was conditioned with 200 g/t Potassium Amyl Xanthate (PAX) as the primary collector. Frother dosage consisted of 3 mL of Interfroth F228 neat in 200 L (15 ppm) of recirculating water, added during conditioning. The conditioned slurry was fed into the HydroFloat™ cell at a controlled rate. Two fluidisation water flow rates (2 L/min and 3 L/min) were tested to assess their effects on fluidised bed stability and flotation performance. Air was injected at 20% of the respective fluidisation water flow rate to ensure consistent bubble dispersion during flotation. During operation, the concentrate was collected via the overflow launder, and tailings were collected from the underflow stream.

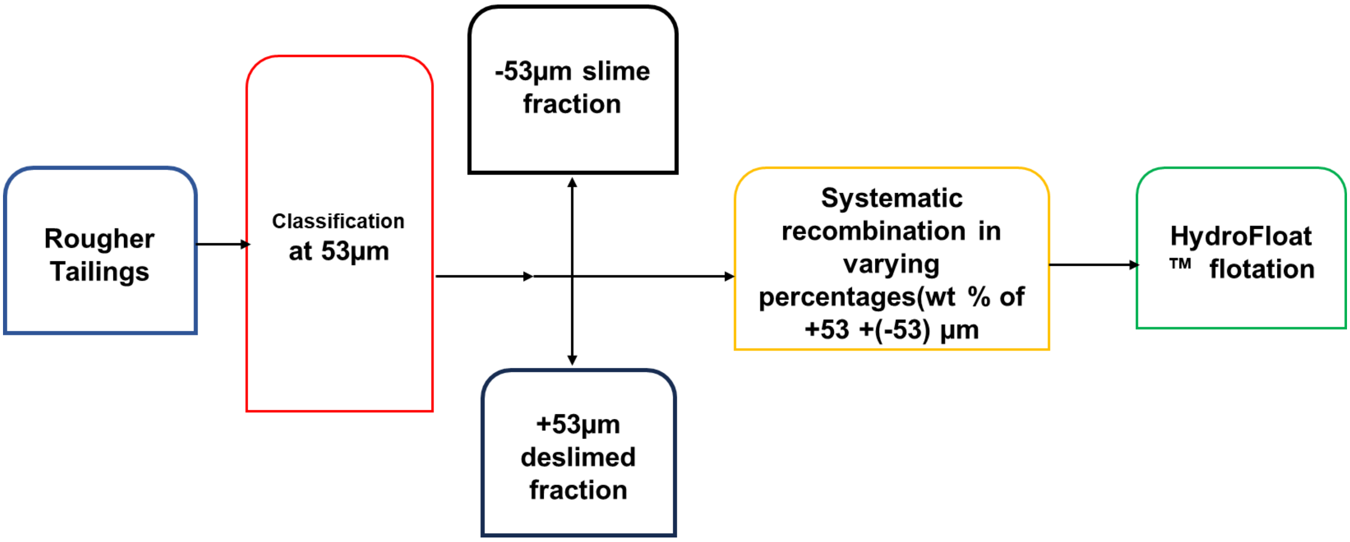

Fig. 2. Flowsheet of the experimental methodology.

3.Results

3.1 Mass recovery and fines Carry-over

Mass recovery systematically increased with slimes at both water rates (Fig. 3). At 2 L/min, mass recovery rose from approximately 10–15 % at less than 10 % slimes to about 45–50 % at around 67 % slimes. At 3 L/min, the increase was steeper, from roughly 30–35 % to 75–80 %. The upward curvature above roughly 40% slimes at 3 L/min indicates a shift to entrainment-dominated behaviour and a narrower stable operating window. The accompanying plot (Fig. 4) shows that, at fixed conditions (3L/min), the mass of −53 µm reporting to concentrate increases linearly with fines added. This near-proportional "fines-in"- "fines-out" relation suggests a roughly constant fines-entrainment coefficient; as the fines fraction increases, that term dominates total mass pull. Practically, the product becomes fines-rich with clear implications for downstream processes.

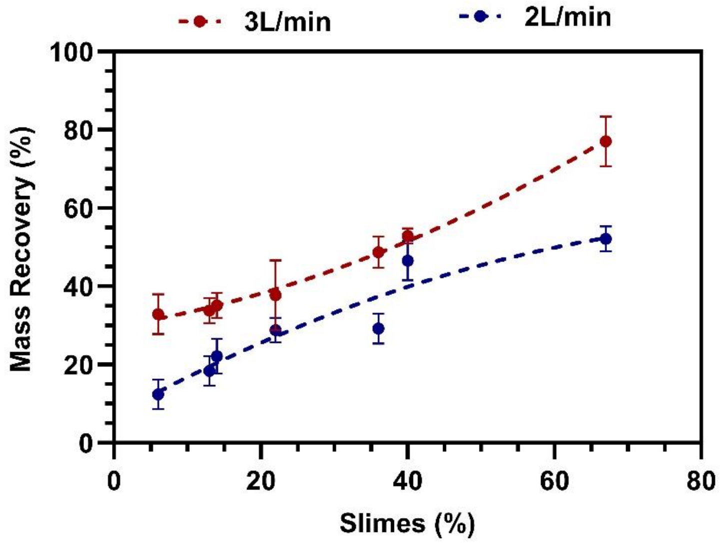

Fig. 3. Effect of fines and teeter-water rate on HydroFloat™ mass recovery. Mass recovery increases monotonically with slimes, with a stronger rise at 3 L/min.

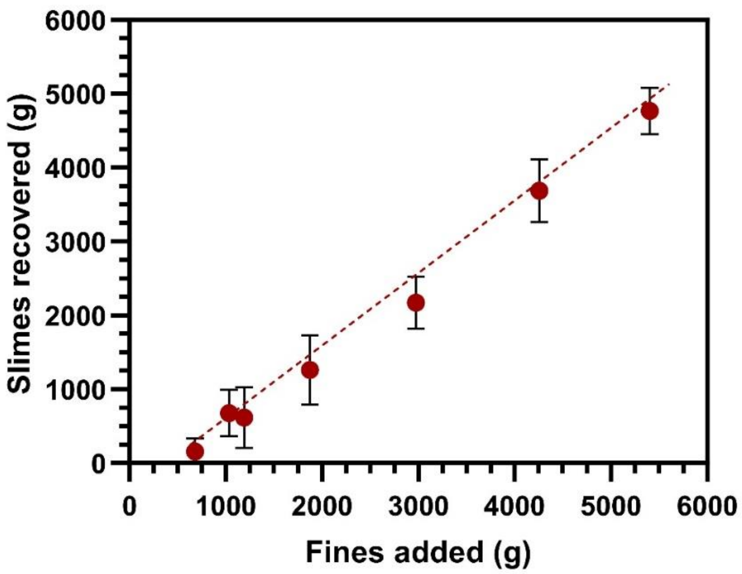

Fig. 4. Linear scaling of fines carry-over with fines addition in HydroFloat™ at fixed operating conditions.

3.2 Operational insights: Bed stability and Concentrate characteristics

The stability and performance of the fluidised bed varied significantly between un-deslimed (67% slimes) , partially deslimed (36% slimes), and fully deslimed feed (6% slimes), as shown in Fig.5. The un-deslimed bed exhibited poor stability, with high segregation within the fluidised bed (no interface visible), and fines disrupting particle fluidisation. It is important to note that the fully deslimed feed used in this study (6% slimes) is much finer and more uniform than the conventional feeds typically reported for HydroFloat™ applications. Even the deslimed fraction (+53 µm) lies within a finer-than-usual size range. Under these conditions, the visual distinction of a sharp bed interface becomes less evident because the particle size distribution is relatively narrow, producing a more homogeneous suspension. By contrast, in a partially deslimed feed (Fig.5b), an apparent interface may emerge simply due to the stark contrast between coarse and fine fractions; however, this does not necessarily reflect a true equilibrium "bed level" but rather a visual of the bimodal size distribution. This distinction is important for interpreting the results: the absence of a clear interface in the fully deslimed feed does not indicate instability but instead reflects the more uniform settling behaviour of the concentrates recovered from the tests at 67%, 36%, and 6% slimes are shown in Fig.6. There is a clear difference in colour, reflecting the increasing amount of fine gangue, and lack of selectivity when processing feed with higher slime content.

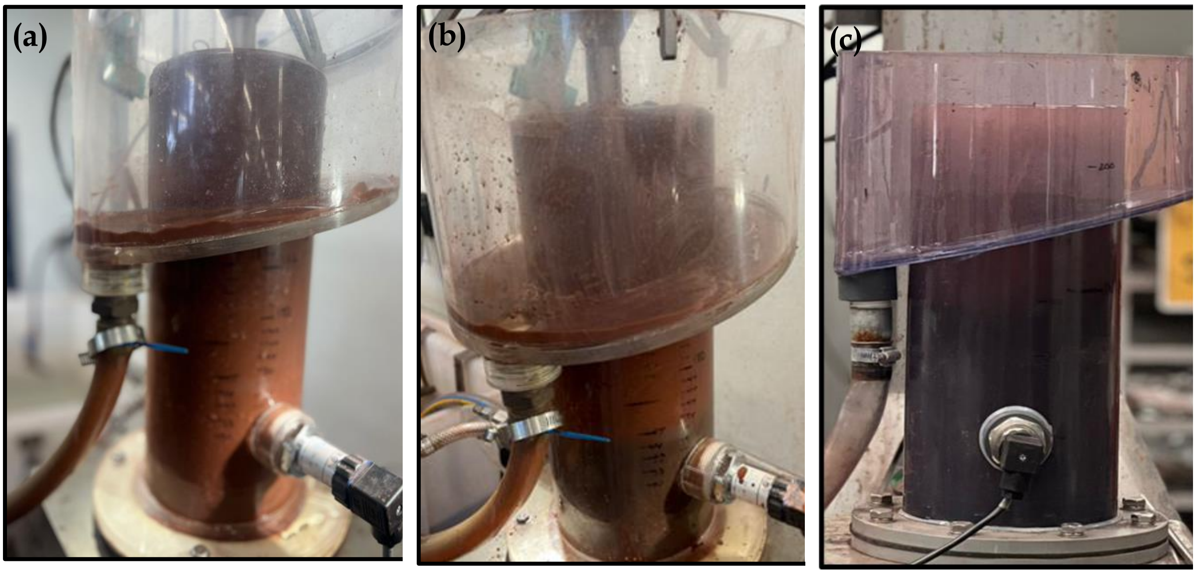

Fig.1. Effect of desliming on HydroFloat™ bed condition (a) undeslimed(67%slimes), (b) partially deslimed(36%slimes), (c) fully deslimed (6%slimes) feeds.

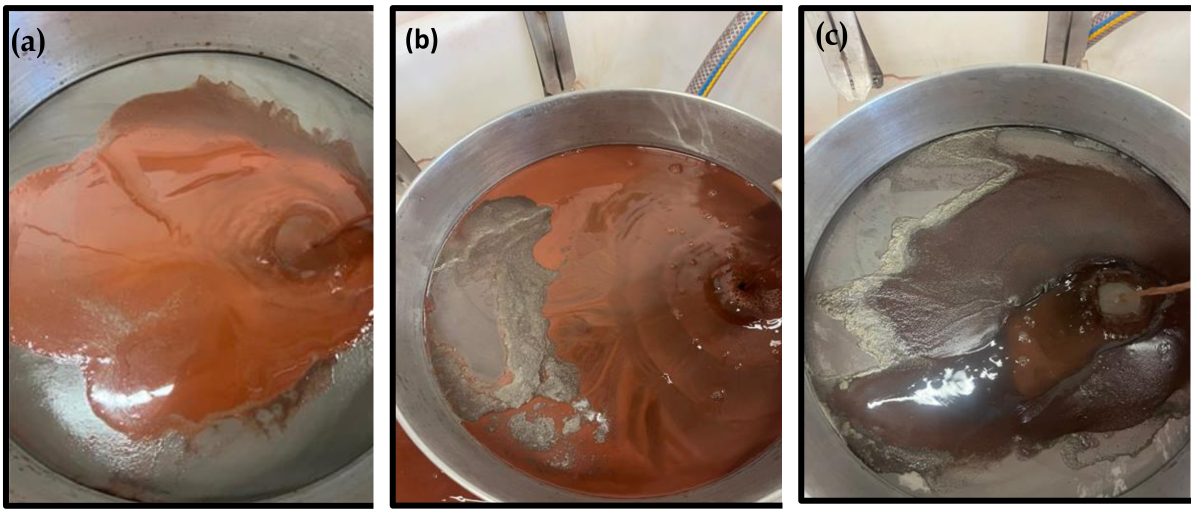

Fig. 6. HydroFloat™ concentrates produced from (a) undeslimed (67% slimes), (b) partially deslimed (36% slimes), (c) fully deslimed (6% slimes) feeds.

4. Conclusion

Overall, the results show that the HydroFloat™ can work relatively effectively with a limited percentage of fines in the feed; however, performance declines beyond a threshold of about 30–40% <53 µm material. Below this level, the fluidised bed remains stable, and true flotation drives mass recovery. Above it, fines entrainment increases sharply, causing concentrate dilution and unstable fluidisation. The findings emphasise the importance of controlled desliming and optimisation of the fluidisation water rate to balance recovery and selectivity. Notably, even with finer-than-usual feed sizes, the HydroFloat™ maintained a stable bed structure, suggesting that with proper hydrodynamic tuning, fluidised-bed flotation can be extended to size ranges typically regarded as unsuitable for coarse flotation.

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