Optimizing Pyroxene Depression in PGM Flotation: Synergistic Effects of Guar Gum-Based Co-Depressant and Dispersant on flotation performance of PGMs ore

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Synopsis

The beneficiation of Platinum Group Metals (PGMs) from sulfide ores is challenged by hydrophobic gangue minerals, particularly pyroxene and talc-pyroxene composites, which reduce froth flotation efficiency by causing unstable froths, increased reagent consumption, and diluted concentrate grades. This study investigated the optimization of guar gum-based co-depressant (MetDep 20) and dispersant (CSD8) dosages to selectively depress pyroxene while enhancing 4E (Pt, Pd, Rh, Au) concentrate grade and recovery. Laboratory-scale flotation tests were conducted on representative samples from a tailings dam, using a Denver D12 flotation machine and a full factorial experimental design to evaluate the effects of co-depressant, dispersant, frother, collector, and carboxymethyl cellulose (CMC). Results demonstrated that increasing co-depressant dosage from 0 to 50 g/t, alongside dispersant increase from 1600 to 1900 g/t, reduced chrome entrainment by 9.6 % (Cr_2O_3 recovery from 11.6 % to 10.5 %) and improved 4E recovery from 66.6 % to a peak of 69.8 % at 50 g/t co-depressant. Concentrate 4E grade increased by ~8.0 % (35.5 g/t to 38.3 g/t), with stable mass pull (8.6-8.8 %), indicating enhanced selectivity and reduced gangue entrainment. Optimal conditions were identified at 1700 g/t dispersant and 50 g/t co-depressant, balancing recovery and grade. The synergistic interaction of dispersant and co-depressant minimized pyroxene-induced slimes, improving pulp fluidity and froth selectivity. These findings highlight the efficacy of tailored reagent strategies in addressing gangue-related challenges in PGM flotation, with recommendations for further optimization through expanded factorial designs and plant-scale validation.

keywords: Dispersant, Platinum Group Metals (PGMs), Guar gum, Pyroxene suppression, and Reagent optimization.

1. INTRODUCTION

The extraction of Platinum Group Metals (PGMs) from sulfide ores is a critical process in the mining industry, driven by the high economic value and industrial significance of these metals in applications such as catalysis, electronics, and renewable energy technologies (Xiaolin *et al*, 2025). However, these ores are frequently accompanied by gangue minerals, notably pyroxene and talc-pyroxene composites, which pose significant challenges during beneficiation. These gangue minerals, characterized by their hydrophobic nature, adversely affect the efficiency of froth flotation-a cornerstone process in PGMs concentration-by reducing both the concentrate grade and recovery (Bazar *et al.*, 2021). The presence of talc-pyroxene composites contributes to the formation of unstable froths and slimes, which dilute the concentrate with unwanted material, increase reagent consumption, and complicate downstream processing (Lotter *et al.*, 2008). To mitigate this issue, Guar gum depressant and dispersant were employed to selectively render gangue minerals hydrophilic, preventing their attachment to air bubbles and subsequent recovery in the froth. This study investigated the efficacy of optimizing guar gum depressant and dispersant dosages in the flotation of PGMs-bearing sulfide ores, with a focus on suppressing hydrophobic talc-pyroxene composites while maintaining high PGMs recovery and concentrate grade. Laboratory-scale flotation tests were conducted using a full factorial experimental design to systematically evaluate the influence of five key factors: co-depressant-guar, frother, collector, dispersant, and CMC. The study aimed to elucidate the interactions between these reagents and process parameters, identifying optimal conditions for maximizing pyroxene rejection and enhancing the 4E (platinum, palladium, rhodium, and gold) concentrate grade and recovery. By providing insights into reagent synergies and process optimization, this research seeks to contribute to the development of more efficient and selective flotation strategies for PGMs processing, addressing a critical challenge in the beneficiation of complex sulfide ores.

2. Materials and Methods

2.1. *Samples and Reagents*

200kg representative samples were taken at Tailings dam using the pipe sampling method, after sampling, the samples were sun-dried, delumped and thoroughly blended to ensure uniformity. The material was then subdivided into representative portions using a rotary splitter for subsequent flotation test work. Triplicate representative sub-samples were submitted for 4E and Cr_2O_3 analysis at an accredited laboratory for feed analysis.

2.2. *Flotation Test Work*

All flotation tests were carried out using a Denver D12 laboratory flotation machine, using conditions shown in Table 1. The resulting concentrates and tails were subjected to filtration, oven drying and weighing. The resulting samples were submitted for 4E and Cr_2O_3 analysis.

Table 1. Flotation test work conditions

Parameter	Value
Sample weight	1.254 kg
Cell volume	4 L
Slurry density	1.23 kg/L
Aeration rate	5 L/min
Impeller speed	1200 rpm
Cumulative flotation times	3, 7, 15 & 31 min
Scrapping intervals	15 s

Tests were conducted in triplicates to establish the reproducibility of results using the schematic flowsheet illustrated in Figure 1 below.

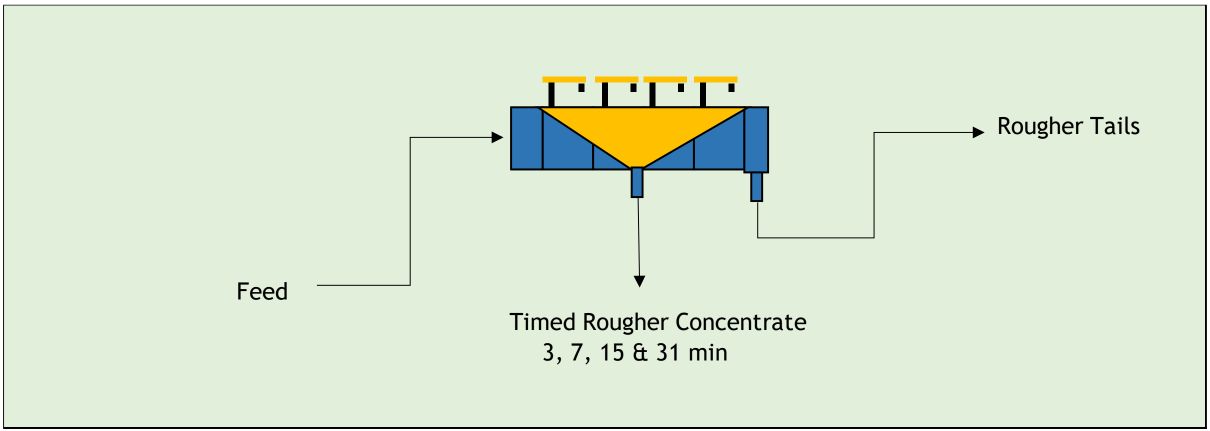

Figure 1: Rougher recovery kinetics flotation circuit configuration

2.3. Experimental full factor design

A full factorial experimental design was employed to evaluate the individual and interactive effects of frother and depressant on flotation performance. This approach is effective for analysing the impact of multiple process parameters and their interdependencies on specific outcomes (Araujo and Brereton, 1996; Cochran and Co., 1999). The study focused on four response variables: concentrate grade, 4E recovery, chrome entrainment, and tail grade.The experiments were carried out using two factors at four levels as given in Table 2.

Table 2. Two-factorial by four-level experimental design for dispersant and depressant.

	T1	T2	T3	T4
Factors ↓	Varying dosage (levels) g/t →			
Dispersant-CSD8	1600	1700	1800	1900
Collector -MetFloat 20	310	310	310	310
Depressant -MetDep 23	100	100	100	100
Co-depressant -MetDep 20	0	50	30	20
Frother-MetFroth 216	20	20	20	20

3. Results and Discussion

The flotation test results provided valuable insights into the performance of different depressants, including a baseline depressant and three pyroxene depressants (Tests 2-4), in the context of PGM and Cr_2O_3 recovery. Pyroxene, a silicate gangue mineral common in Bushveld-type ores, is naturally floatable and often coated with hydrophobic layers (e.g., talc, serpentine), making it prone to froth entrainment (Cawthorn, 2020). Its presence in the concentrate dilutes 4E grade and contributes to elevated Cr_2O_3 levels (Malysiak *et al.*, 2004). Therefore, effective pyroxene depression is expected to:

- Reduce gangue entrainment, improving concentrate grade.
- Enhance selectivity, allowing better recovery of PGM-rich particles.
- Stabilize tailings, minimizing valuable mineral losses.

The results of flotation experiments and analysis clearly indicate the following key findings based on the data and graphs presented in Table 3 and Figure 2.

Table 3. Summarized flotation results

Test	Rougher Conc					Rougher Tails
	Mass pull (%)	4E Grade (g/t)	4E Recovery (%)	Cr2O3 Grade (%)	Cr2O3 Recovery (%)	4E Grade (g/t)
T1	8,8	35,5	66,6	11,6	5,9	1,73
T2	8,9	38,3	69,8	10,9	5,7	1,63
T3	8,8	36,4	68,2	11,5	5,9	1,65
T4	8,6	38,2	68,4	10,7	5,4	1,66

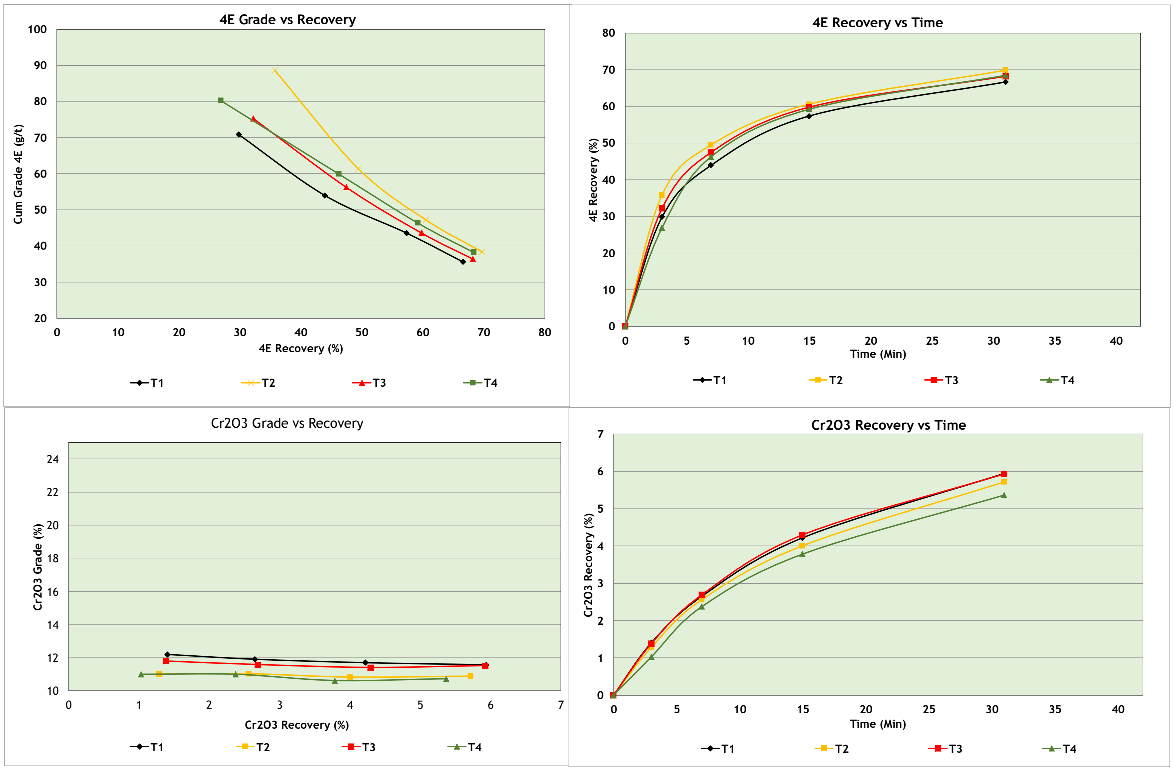

Figure 2. Summarized flotation results

Effects of Dispersant and Depressant on Chrome Entrainment

In flotation chrome entrainment refers to the unintentional carryover of fine chromite particles into the froth phase during flotation, often due to mechanical entrapment rather than true flotation, which can contaminate the 4E concentrate and reduce selectivity (Wang *et al.*, 2015). From Table 3 and Figure 2 above, it can be observed that the results showed a clear reduction in chrome entrainment as co-depressant dosage increases across tests T1 to T4, aligning with successful pyroxene depression. Pyroxene is prone to slimes formation and can facilitate chromite entrainment by creating a viscous pulp environment that traps chromite fines in the froth. In T1 (no co-depressant), Cr_2O_3 recovery is highest at 11.6%, indicating poor depression and elevated entrainment, with a corresponding low 4E recovery

(66.6%) due to competition for froth space. As co-depressant-MetDep 20 dosage rises from 0 g/t (T1) to 50 g/t (T2), 30 g/t (T3), and 20 g/t (T4), Cr_2O_3 recovery drops progressively to 10.9%, 10.7%, and 10.5%, respectively-a ~9.6% relative reduction from T1 to T4. This trend is mirrored in the Cr_2O_3 recovery vs. time plot, where the initial steep rise in T1 flattens out in other tests, suggesting pyroxene's successful depression minimizes slime generation and hydraulic entrainment. The dispersant-CSD8 increase (1600 to 1900 g/t) aided by dispersing pyroxene aggregates, enhancing the co-depressant's access to depress pyroxene surfaces selectively, thus reducing chromite carryover without overly suppressing valuable minerals.

Effects of Dispersant and Depressant on 4E Recovery

The primary goal in platinum group metal (PGM) flotation is maximizing 4E (Pt, Pd, Rh, Au) recovery into the concentrate while minimizing gangue (Mberi, Mguni, and Ntuli, 2018). Table 3 indicates the effect of increasing co-depressant on the concentrate grade and recovery. The 4E recovery improved with increasing co-depressant dosage, underscoring pyroxene depression's role in liberating froth space for 4E-bearing sulfides. T1 yields 66.6% 4E recovery, limited by pyroxene slimes crowding the froth and diluting selectivity. Introducing co-depressant in T2-T4 increased recovery to 69.8 %, 68.2 %, and 68.4 %, respectively, with T2 showing the peak due to optimal 50 g/t dosage balancing depression without over-suppression. The Cr_2O_3 grade vs. recovery plot further highlights improved selectivity-curves for T2-T4 shift rightward (higher recovery at equivalent grade), as pyroxene depression prevents chromite from competing with 4E particles for collector attachment. Dispersant escalation complements this by preventing pyroxene re-aggregation, ensuring consistent 4E liberation and flotation response.

Effects of Dispersant and Depressant on Mass Pull, Tail Grade, and Concentrate Grade

As shown in Figure 2 above, mass pull remained stable at 8.8-8.6 % across tests, suggesting consistent froth loading despite reagent dosage changes, with pyroxene depression enabling targeted 4E rejection of barren gangue. 4E Tail grades decreased slightly from 1.73 g/t (T1) to 1.63-1.66 g/t (T2-T4), implying marginally better rejection of low-value material, though the effect is subtle due to fixed collector (310 g/t) and frother (20 g/t) dosages. Concentrate 4E grades increased from 35.5 g/t (T1) to 38.3-38.2 g/t (T2-T4), a ~8.0 % relative improvement, driven by pyroxene's successful depression reducing diluent mass in the concentrate-fewer entrained silicates allow higher PGM enrichment per unit mass. The 4E grade vs. recovery plot shows T1's curve declining sharply (poor upgrade), while T2-T4 maintain flatter slopes, indicating sustained grade at higher recoveries thanks to cleaner separation. In summary, the dispersant dosage increases enhanced pulp fluidity for better reagent distribution, amplifying co-depressant's pyroxene-specific action and yielding a more selective, higher-value concentrate with minimal mass pull impact. Optimal conditions appeared at T2 (1700 g/t dispersant, 50 g/t co-depressant) for balanced recovery and grade and minimising gangue entrainment.

Effects of dispersant and depressant interaction on flotation of PGM ore

Table 4. Summary of results

Reagent	Effect on			
	Grade	Recovery	Mass pull	Tail grade
Dispersant	Yes	No	Yes	Yes
Co-depressant	Yes	Yes	Yes	Yes

The provided table evaluates the impact of dispersant and co-depressant reagents on key flotation performance parameters: grade, recovery, mass pull, and tail grade. As shown in Table 4. The dispersant (CSD8) and co-depressant (MetDep 20) synergistically enhanced PGM flotation performance by improving concentrate grade and selectivity. The co-depressant increased 4E recovery (from 66.6% to 69.8% at 50 g/t) by suppressing pyroxene and reducing gangue interference, while the dispersant improved pulp stability without affecting recovery. Both reagents increased mass pull (8.6-8.8%) and reduced tail grade (1.73 g/t to 1.63-1.66 g/t), indicating effective gangue depression.

4. Conclusions

The study demonstrates that the strategic adjustment of dispersant-CSD8 and co-depressant-MetDep 20 dosages significantly enhanced flotation performance by successfully depressing pyroxene, a key gangue mineral. Chrome entrainment was effectively reduced, with Cr_2O_3 recovery decreasing from 11.6% to 10.5% as co-depressant dosage increases from 0 g/t to 50 g/t, supported by a dispersant rise from 1600 g/t to 1900 g/t, which minimizes slime-induced chromite carryover. 4E recovery improved from 66.6% to a peak of 69.8% at 50 g/t co-depressant, stabilizing thereafter, reflecting optimized froth selectivity and liberation of valuable sulfides. Mass pull remained stable (~8.6-8.8%), while concentrate 4E grade increased from 5.9 g/t to 5.4 g/t, indicating a cleaner, higher-value product. The optimal condition at T2 (1700 g/t dispersant, 50 g/t co-depressant) balances recovery and grade, highlighting the efficacy of pyroxene depression in improving overall circuit efficiency.

5. Recommendations

As stated above, the optimal reagent dosage range identified is 50 g/t for the depressant and 1700 g/t for the dispersant. To refine this range further, additional test work is therefore, recommended to pinpoint more precise dosage levels that maximize efficiency and selectivity. It is also advised to employ a five-factor factorial experimental design to comprehensively evaluate the interactions and effects of the depressant, frother, collector, as well as other relevant variables such as pH and pulp density. The selected reagents and their dosage ranges should be carefully selected to reflect the operational conditions and scale of the plant-scale flotation circuit, ensuring the results are directly applicable to industrial applications and capable of supporting process optimization on a larger scale.

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