UX7 spiral: Ultrafine processing made possible

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In the platinum group metals (PGM) processing circuits, the run of mine ore is milled to fully liberate PGMs for efficient recovery by flotation. For ores that contain chromite, the associated chromite is recovered as a byproduct or discarded as tails from the PGM recovery circuit. Primary or secondary PGMs report to the spiral's circuit to recover and upgrade the contained chromite. Due to the primary objective being the liberation of PGMs, the chromite particles are usually ground too fine by the milling process. When the very fine material is presented to the spirals, the efficiency of the spirals is reduced. Heavy minerals spirals can typically process fine material from 45 to 1000 µm. To improve separation efficiency, the feed to the spirals is usually deslimed to remove material below 45 µm. Ultrafine high-grade chromite material (material under 75 µm) was seen to still be misplaced to the spiral tailings stream even though the desliming of the material was done upfront. The paper aims to evaluate the effect of geometrical change on the spiral concentrator when processing ultrafine chromite ore. Various design and operational parameters were tested to evaluate the effect on grade, mass yield, and recovery.

The outcome of this study shows that the UX7 spiral can be used to improve mass yield and recovery while processing fine material. The increase in yield and recovery was shown to be more significant for the ultra-fine material. The UX7 spiral showed a 9% higher mass yield and 13% higher recovery than the HX5 spiral. The feed rate and feed solids concentration on spirals are vital in the overall performance. The optimal feed rate and solid concentration on the UX7 were found to be 5tph and 40% solid concentration by weight. Desliming the material before processing on spirals resulted in improvements in grade, mass yield, and recovery, although caution needs to be exercised to avoid losing more fines desliming at a cut point of 10 µm is recommended.

Introduction

South Africa possesses abundant natural resources (Krogscheepers & Gossel, 2015) and its mining sector contributes significantly to the GDP of the country (Pelders & Nelson, 2019). The mining sector continues to be a key contributor to the development and growth of the economy. Contributions are significantly noticed in the areas of GDP, foreign exchange income, tax and royalty, employment and research (Ndansi, 2018). Mining of the platinum group metals (PGMs) is particularly noteworthy, with South Africa being a major global producer of the PGMs and chrome (Lydall, 2009). South Africa holding approximately 75% of the world's PGM reserves makes the PGMs being the current primary revenue generator (Maharaj, *et a*l., 2011). Since the year 2000, PGM price has been on a rise leading to its production replacing gold as the key mineral export of South Africa's PGM processing circuits (Krogscheepers & Gossel, 2015). The Bushveld Complex is home to the biggest chromite reserves globally, and the largest reservoir for the platinum-group elements. Large volumes of chromite in South Africa are extracted from this host rock (Dzvinamurungu, *et al.*, 2020).

PGM processing circuits regularly consist of an MF2 (Mill-Float-Mill-Float) where the primary grind is in the region of 30-40% -75 µm followed by a more precise secondary grind (Hay & Schroeder, 2005) to achieve an 80 wt% passing 75 µm (Dzvinamurungu, *et al.,* 2020) in order to completely liberate the PGMs. Each grind stage is followed by its flotation circuit for efficient recovery of PGMs, typically for the treatment of UG-2 platinum ores. Most secondary milling circuit configurations adopt a single-stage ball-mill for the grinding of the primary flotation tails, followed by secondary flotation (Maharaj, *et al.*, 2011). The purpose of fine grinding is for the liberation of the locked PGMs in composite silicate gangue particles for potential improvement in the concentrate grade and yields (Rule, *et al.*, 2008).

Mineralisation of the UG-2 platinum group is extremely intricate and has always posed difficulties because of the high chromite content in the ore input. Additionally, the flotation process often leads to the inclusion of the chromite in the final PGMs concentrate, mainly due to entrainment. Consequently, the high chromite contained in the floatation concentrates impacts the downstream smelting process (Nel, *et al.*, 2005). Elevated chromite levels are to be avoided in the furnaces that process PGMs to prevent incurring financial penalties (Rule, *et al.*, 2008) in the final saleable product from smelter.

Flotation tailings after extraction of PGMs still have a high content of chromite (Dzvinamurungu, *et al.*, 2020) due to the fact that chromite does not get recovered by flotation processes (Nel, *et al.*, 2005) and typically the feed to the secondary mill contains significant amounts of chromite(Maharaj, *et al.*, 2011). The PGM tailings are usually kept at a tailings disposal area (Rule, *et al.*, 2008) or processed further to recover the contained amounts of chromite still present in the tailings (Nel, *et al.*, 2005). The tailings rich in chromite are fed into the gravity concentrator plant to recover the chromite as a value-adding by-product of the process. (Dzvinamurungu, *et al.*, 2020) through achieving a saleable chromite grade in the final concentrate. The operational simplicity and low operational cost of the gravity concentration method make it the preferred option.

The more precise secondary grind (Hay & Schroeder, 2005) aimed at achieving a product of 80 wt% passing 75 µm (Dzvinamurungu, *et al.*, 2020) to completely liberate the PGMs resulting in high generation of ultrafine material. The material with a high amount of ultrafine ends up being used as feed to the gravity concentration plant. Separation efficiency on the spirals is dependent on feed particle size, and the more ultrafine material is present the lower the separation efficiency achievable. For instance, feed material with high fines content results in an increased viscosity effect which affects the material flow on the spiral circuit. The primary difficulty in operating spirals for chromite recovery is the fine and ultrafine material produced by milling (Murthy & Tripathy, 2020) when liberating PGMs.

To improve separation efficiency, the feed to the spirals is usually deslimed to remove material below 45 µm. Ultrafine high-grade chromite material (material under 75 µm) was seen to still be misplaced to the spiral tailings stream even though desliming of the material was done upfront (Murthy & Tripathy, 2020). This paper aims to evaluate the effect of geometrical change on the spiral concentrator when processing ultrafine chromite ore. Decreasing these losses would not only improve the plant performance but also make the economics of the operations more attractive.

Various design and operational parameters will be tested to evaluate the effect on grade, mass yield, and recovery. This will be achieved through conducting test work using the newly developed Multotec ultrafine spiral concentrator known as the UX7 spiral.

Literature review

PGMs in South Africa

PGMs are considered the main contributor to the increase in Southern African mining production in 2021 (Felthun, *et al.,* 2021). South Africa contains more than 80% of the world-reserves of PGMs (Afolabi, *et al.,* 2012). The PGMs include platinum, palladium, rhodium, ruthenium, iridium, and gold. The main source of PGMs is the Bushveld Complex which consists of the mineralised horizons of Merensky Reef, Upper Group Two (UG2) chromite, and the Platreef (Zientek, *et al*., 2014). Figure 1 shows the Bushveld Complex which is subdivided into five distinct areas.

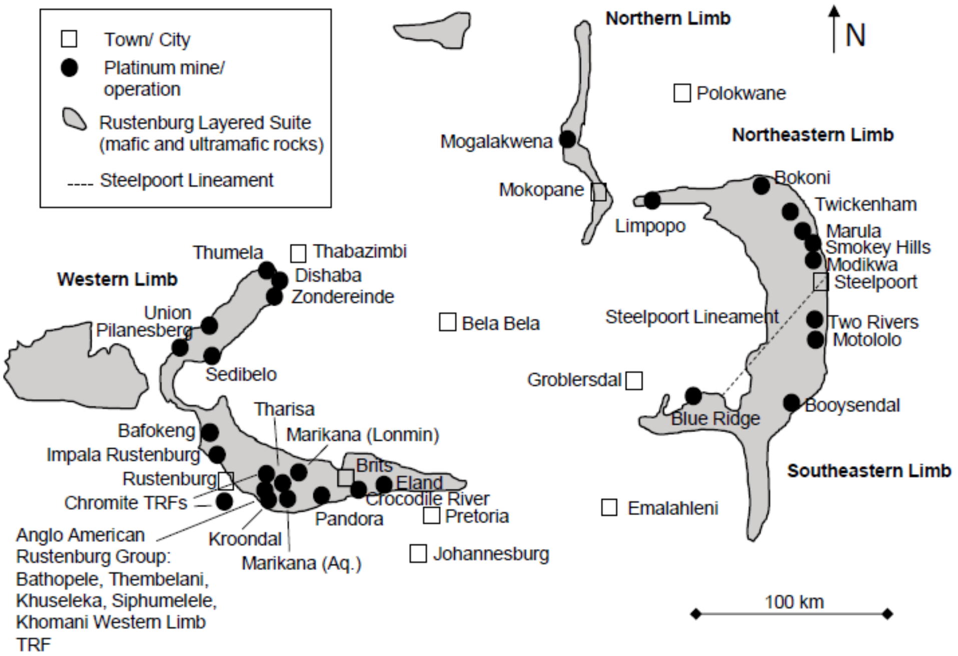

Figure 1.: Bushveld Complex geological map. (Thormann, et al.*, 2017).*

The Bushveld Complex is subdivided into five limbs: the eastern, western, far western, northern, and south-eastern which is shown above (McCall, 2016). Mining activity is focused on the western and eastern limbs because the Merensky and UG2 reefs are the most dominant reefs in those regions. The Merensky and UG2 reefs consist of about 90% of the total platinum and palladium in the Bushveld Complex (McCall, 2016) with layers of chromite ore. The chromite layers are formed through either gravity settling or influxes of magma with different compositions. Variations occur in mineral compositions, phase abundances, textures, and/or the mode of occurrence of minerals. The western limb consists of predominately Pt-Fe alloys, and the other limbs have PGE-sulfides (McCall, 2016). The variation in the reef characteristics affects the PGM beneficiation process and to ensure a high degree of recovery of PGM requires ultrafine grinding for PGM liberation. Also, considerations into the removal of the very high chromite contents in the beneficiation process are required.

PGM Beneficiation Process

The recovery of PGM is typically achieved through beneficiation using multistage milling and froth flotation. The milling schedule of the PGM mineral ore is important because undergrinding results in poor recovery of PGM because of poor liberation. Overgrinding wastes energy as well as high production of fines (McCall, 2016). PGM processing circuits regularly consist of an MF2, as shown in Figure 2 where the primary grind is in the region of 30-40% -75 µm followed by a finer secondary grind (Hay & Schroeder, 2005) to a target grind of 80 wt% passing 75 µm (Dzvinamurungu, *et al.*, 2020) to fully liberate PGMs. Each grind stage is followed by its flotation circuit (Maharaj, *et al.*, 2011) for efficient recovery of PGMs typically for the treatment of UG-2 platinum ores. Most secondary milling circuit configurations adopt a single-stage ball-mill for the grinding of the primary flotation tails, followed by secondary flotation (Maharaj, *et al.*, 2011). Liberation and association of the PGM determine the mineral floatability (Nel, *et al.*, 2005). The particle size and association of PGMs is classified into four classes, namely, the liberated platinum group, platinum group associated with iron sulfides and base metals, and platinum group that exists locked in silicates (Nel, *et al.*, 2005). The PGM associated with silicates is the hardest to float.

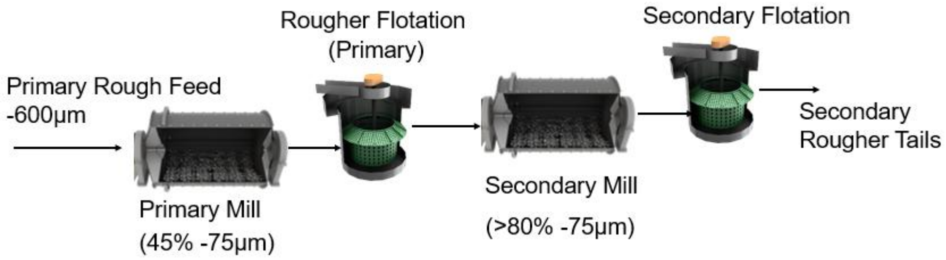

Figure 2. Mill-Float-Mill-Float circuit

Froth flotation is a process used to recover the PGMs based on their physical and chemical characteristics. Hydrophobic minerals, such as base metal sulfides (BMS) PGMs, are collected on the froth (air bubbles) which move to the surface of the flotation cell and are considered the concentrate. Hydrophilic minerals, such as silicates and oxide), sink to the bottom of the flotation cell (McCall, 2016) which are reported to be apart from tailings and this is because chromite does not respond to flotation.

PGMs that are entrapped inside gangue particles or hosted within chromite are likely to be unrecoverable and thus report to the tailings. The UG2 reef is considered to have high chromite, which is inclusive of the Bushveld Complex, and chromite is seen to be hydrophilic and thus does not float naturally (McCall, 2016). This makes the beneficiation of PGM challenging and to increase recovery efficiency, fine milling is required as this promotes the liberation of the PGMs. This leads to the chromite influencing the milling schedule which aims to efficiently liberate gangue particles (BMS) and PGM particles (McCall, 2016). Even though chromite does not respond to flotation, ultrafine chromite particles tend to report the flotation concentrate due to their particle size (Nel, *et al.*, 2005). This is unfavourable as the increase in chromite influences the flotation efficiency as well as the smelting process. Chromite contamination into the flotation concentrate results in issues for smelter feedstock produced (Rule, *et al.*, 2008). Typically the feed to the smelters requires less than 3% chrome (Nel, *et al.*, 2005) and this is controlled through the reduction of the generation of chrome slimes produced through the overgrinding in the secondary milling step and the restriction of water recovery (Nel, *et al.*, 2005).

Chromite Beneficiation Process

The high chromite recovery in the final tailings from an MF1-MF2 circuit, in Figure 2, is further beneficiated in a spiral plant for the upgrading of the chromite mineral. This material typically has an 80% cumulative passing at 75 µm (Hay & Schroeder, 2005). A modified version of this circuit entails the recovery of the chromite from rougher tailings after MF1 which is typically 45% cumulative passing at 75 µm. The first suggestion of removing the chromite fraction from the first rougher stage tails is good because the primary rougher tails are only partially ground; the bulk of the chrome results are in the coarse fraction and hence easily recoverable (Afolabi, *et al.*, 2012) allowinf for better PGM recoveries. The removal of the coarse chromite particles from the rougher tails is shown in Figure 3.

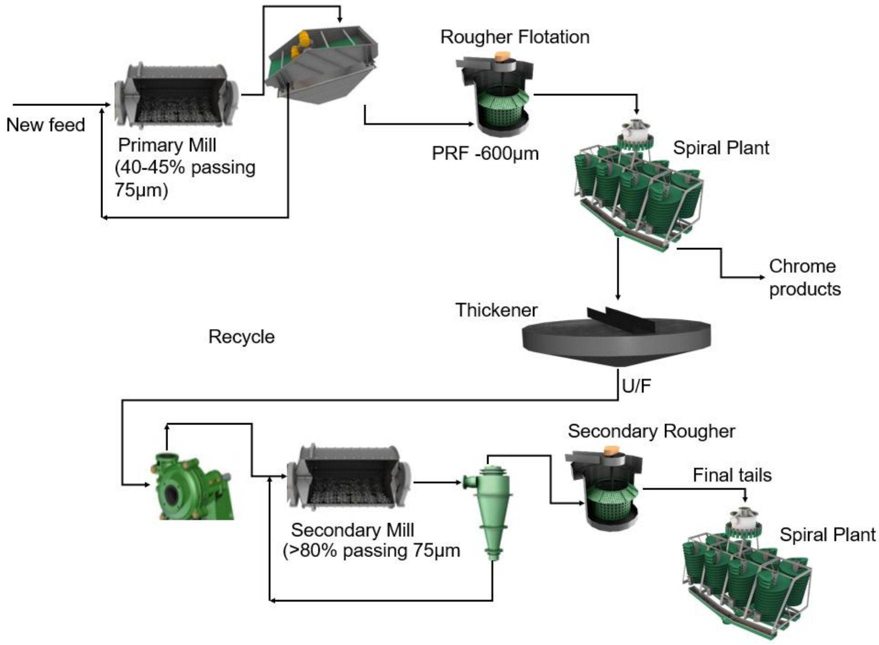

Figure 3: Schematic representation of an alternative flotation plant

The tailings rich in chromite are fed into the gravity concentrator plant to recover the chromite as a value adding by-product to the process (Dzvinamurungu, *et al.*, 2020) by achieving a saleable chromite grade in the final concentrate. (Tripathy, *et al.*, 2010). The operational simplicity and low operational cost of the gravity concentration method make it the preferred option (Tripathy, *et al.*, 2010).

Multotec spiral concentrators used for heavy minerals usually take a feed particle size distribution (PSD) of a top size of 1000 µm and a bottom size of 38 µm. For many spiral concentrators the more closely sized of the material being processed, the better the efficiency of the separation (Afolabi, *et al., 2012)* The primary difficulty in operating spirals for chromite recovery is the fine and ultrafine material produced by milling (Murthy & Tripathy, 2020) when liberating PGMs. The conventional chromite beneficiation circuit uses spiral concentrators for the recovery of ultrafine chromite, and it has been seen that spiral efficiency decreases with a decrease in particle size (Tripathy, *et al.*, 2010).

Spiral Concentrators

Spiral concentrators can be used through multiple stages for upgrading from feed grade to a saleable product. There is a strong recommendation for spirals due to their ease of use, and low operating costs, and it is considered simple. Spiral concentrators separate based on the density of differential of particles. Particles with a higher density are expected to report close to the centre column on a spiral with the lower density further away from the spiral trough (Boucher, et al., 2016). The product is collected as a concentrate, middlings, and tailings products as shown in Figure 4. Particle size plays a significant role in the efficiency of chrome recovery during concentration using spirals.

Historically it has been seen that the spirals have lower performance below a particle size of 300 µm. When more than 10% of your material fed to the spirals consists of particles below 45 µm, the efficiency of the spiral drops, therefore a desliming step is required to remove these particles using desliming cyclones. Ultrafine high-grade chromite material (material under 75 µm) was seen to still be misplaced in the spiral tailings stream even though desliming of the material was done upfront (Murthy & Tripathy, 2020). During the beneficiation of chromite ore using spiral concentrators, approximately 50% (by weight) of the total feed is discarded into tailings which typically have a huge quantity of chromite values (Afolabi, *et al.*, 2012). This is a result of high-density material that is ultrafine, reporting as tailings product as shown in Figure 4.

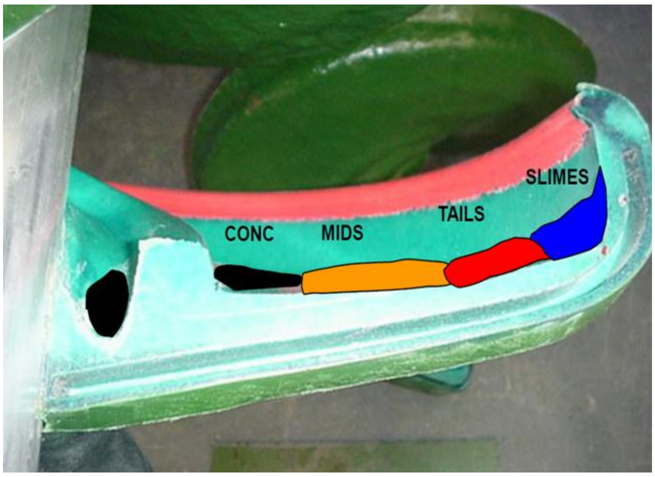

Figure 4: Spiral separation mechanism

Spiral concentrators consist of an open trough that twists downward in a helix configuration about a central axis. The material is mixed with water as a medium to an optimum solids concentration (by weight) and a solids dry tonnage throughput (feed rate). As the slurry flows on the surface of the spiral the particles undergo various forces which include gravity and hydrodynamic forces due to the circulation flow to separate the gangue mineral from the pure mineral. The main process variables of a typical spiral concentrator are the feed flow rate, feed pulp density, and the splitter position (Tripathy, *et al.*, 2010). The product material collected is used to determine the performance of the spiral through the grade, mass yield, and, recovery of the product fractions.

Spiral geometry influences the spiral performance and the results obtained on the spiral products. There are various trough geometries of spirals as the number of turns, length of the spirals, pitch, and diameter of the trough (Boucher, et al., 2016). A large diameter, low pitch, and a high number of turns will give improved separation of fines due to the lower turbulence in slurry (Boucher, *et al.*, 2016). Test work was performed using chromite ore with consideration of the many different pre-types, particle shapes, and size distributions (Boucher, et al., 2016). Depending on the material behaviour to increase the retention time for separation from gangue material to pure minerals which is through a longer spiral achieved by multiple turns on a spiral. There is also a correlation between the particle size and the performance.

The fine material is more efficient on shallow spirals and coarse materials on steeper spirals. The steeper angle spirals assist in avoiding settling or agglomerating of material is known as the beaching of the material.

Materials and Methods

Samples

The study focused on the processing of chromite ore from Mpumalanga and Limpopo province in South Africa. The sample used was a final tailing from PGM MF2 circuits. The sample as received underwent particle size analysis using a Malvern size analyser to confirm the particle size distribution of the material. For this test work samples with a top size of -75 µm and a bottom size of about 10 µm were desired. Where the feed contained material top size coarser than the 75 µm, the samples were milled down to 80% passing 75 µm and deslimed to limit the number of particles below 10 µm.

Methods

Various design parameters and operating parameters were tested to assess the effect on mass yield, grade, and recovery on the UX7 spiral. The following parameters were investigated:

1. Effect of trough angle, number of turns, and number of splitters
2. Effect of particle size; this was also done to establish the maximum top size on the UX7 spiral that does not cause beaching
3. Effect of slimes
4. Effect of solids concentration
5. Effect of feedrate.

The HX5 spiral was tested as a benchmark and compared to the UX7 spiral at two feed material top sizes, that is, the 425 µm and 75 µm. The following test matrix was used for the benchmark. This comparison also served to test the effect of trough angle, number of splitters and the number of turns. Table 1 shows the benchmark test matrix.

Table 1: Benchmark test matrix

Spiral Types and Parameters	**Size Fraction (µm)**	**% Solids Concentration (w/w)**	**Solid Feedrate(tph)**	**Splitter Settings(cms)**			
				SP1	**SP2**	**SP3**	**SP4**
HX5 Spiral (Steep angle, 5 turns, 2 splitters)	-425+0 and -75+0	40	5	60	50	n/a	n/a
UX7 Spiral (Shallow angle, 7 turns, 4 splitters)	-425+0 and -75+0	40	5	50	40	30	25

Table II shows the effect of the size fraction test matrix.

Table II: Effect of top size and slimes test matrix

Size Fraction	**% Solids Concentration (w/w)**	**Solid Feedrate(tph)**	**Splitter Settings(cms)**			
			SP1	**SP2**	**SP3**	**SP4**
-300+0 µm	40	5	30	35	25	25
-150+0 µm	40	5	30	35	25	25
-75+0 µm	40	5	30	35	25	25
Undeslimed (-425+0) µm	40	5	60	40	30	30
Deslimed (-75+10) µm	40	5	50	40	30	25

Table III shows the effect of solid concentration and feed rate test matrix.

Table III: Effect of solid concentration and .feedrate test matrix

Effect of Feedrate						Effect of Solid Concentration					
% Solids Concentration (w/w)	Solid Feedrate (tph)	Splitter Settings(cms)				% Solids Concentration (w/w)	Solid Feedrate (tph)	Splitter Settings(cms)			
		SP1	SP2	SP3	SP4			SP1	SP2	SP3	SP4
40	3	45	45	35	48	30	5	45	45	35	48
40	5	50	40	30	25	50	5	50	40	30	25
40	7	45	45	35	48	60	5	45	45	35	48

Desliming of the material was done using a cyclone test rig as shown in
Figure 5 .

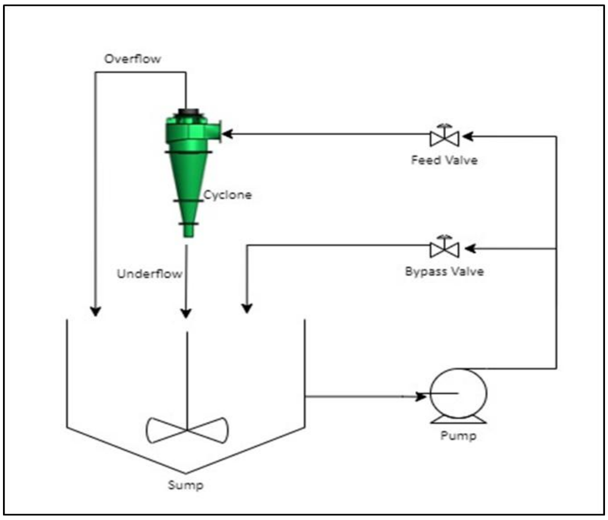

Figure 5 : Desliming cyclone configuration

The desliming cyclone test rig consisted of a Multotec VV100 cyclone model, sump, and pump, and this configuration is shown in
Figure 5 .
The test work was conducted on a spiral test rig as shown in Figure 6. The chromite sample was mixed with water to produce a representative sample with solids concentrations and volumetric flow rates as per the test matrix. The slurry was fed into the spiral feed box via a distributor as per the spiral test rig configuration below.

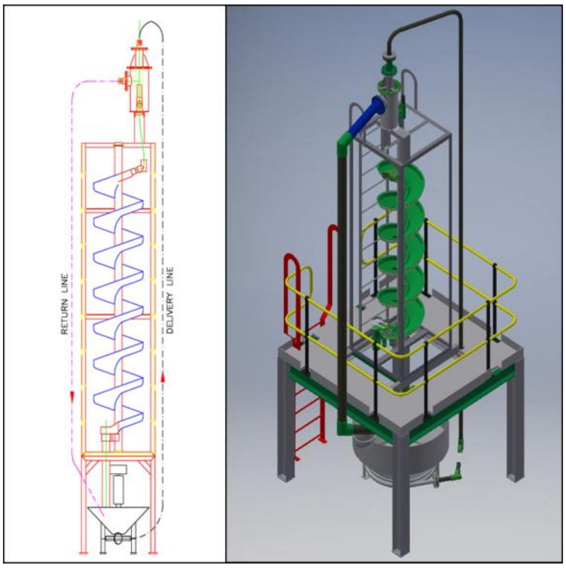

Figure 6: Spiral test rig configuration

The spiral test rig consists of a spiral, sump, and pump. The setup has an overflow connection to ensure continuation circulation and constant feed conditions during test work. UX7 and HX5 test spirals were fitted with an eight-fraction mouth organ product box. The mouth organ configuration is shown in Figure 7:

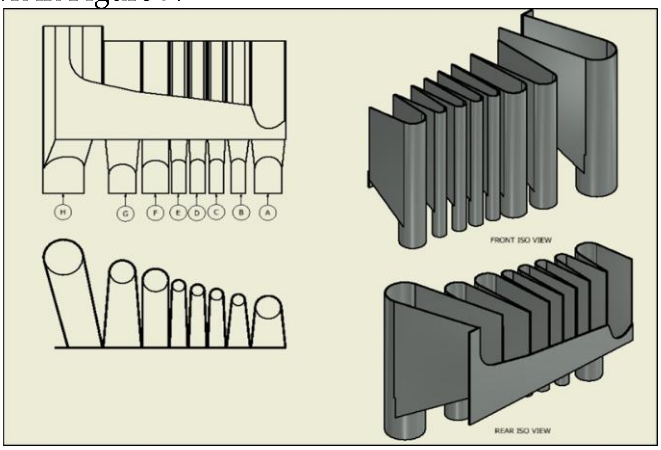

Figure 7: Mouth organ configuration

Mouth organ fraction A represents the sample collected from the inside of the trough, closest to the centre column. It is the heaviest sample and should contain the material of the highest density, i.e., the majority of the Cr_2O_3.

Results and Discussion

Benchmark test

Tables IV and V show the comparison results between the HX5 and UX7 spirals; the spirals were compared using the material with a top size of 425 µm and 75 µm. The -425 µm material had a feed grade of 18 %Cr_2O_3 while the -75 µm had a feed grade of 13 %Cr_2O_3.

Table IV: HX5 and UX7 results (-425 µm)

Product Split	UX7			HX5		
	Mass yield (%)	Grade (%) Cr_2O_3	Recovery (%) Cr_2O_3	Mass yield%	Grade (%) Cr_2O_3	Recovery (%) Cr_2O_3
Conc	40,00	28,03	62.28	40,00	27,67	61.49
Tails	60,00	11.32	37.72	60,00	11.55	38.51

At a 40% mass yield, The UX7 produced a concentrate with 28,03% Cr_2O_3 grade at a recovery of 62.28 %; on the other hand, the HX5 produced a concentrate with 27.67% Cr_2O_3 grade at a recovery of 61.49 %. The HX5 and UX7 at this size fraction showed no significant difference in concentrate grades and recoveries achievable.

Table V: HX5 and UX7 results (-75 µm)

Product Split	UX7			HX5		
	Mass yield (%)	Grade (%) Cr_2O_3	Recovery (%)	Mass yield (%)	Grade (%) Cr_2O_3	Recovery (%) Cr_2O_3
Conc	21,70	21,19	33,97	12,60	21,72	20,98
Tails	78,30	11,42	66,03	87,40	11,86	79,02

For the finer fraction, the UX7 spiral showed a 9% higher mass yield and 13% higher recovery than the HX5 spiral. The achieved concentrate grade was around 21,7 % Cr_2O_3 grade.
The results from the two size fractions indicate that the UX7 can improve mass yield and recovery with the improvements being higher for the finer size material.

Effect of Top Size

Figure 8 shows the PSD curves of the different top-size feed materials tested. This was tested to establish the optimal and maximum size fraction that the spiral can handle without beaching.

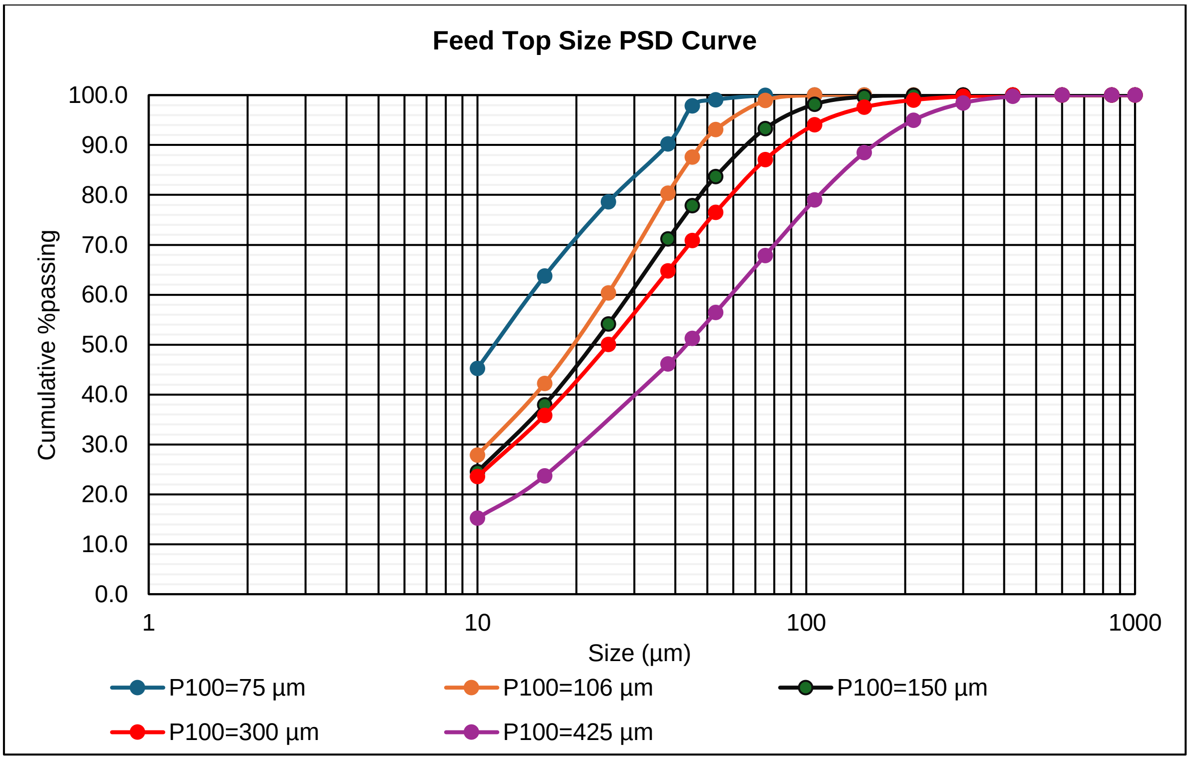

Figure 8: Feed top-size PSD curves

The various samples tested had a P100 of 75 µm,106 µm,150 µm, 300 µm and 425 µm. The corresponding P80 points of these samples varied between 27 and 111 µm. For the various feed top sizes, there was no beaching evident on the UX7 spiral, the material was observed to move smoothly without any build-ups.
Table VI shows the spiral test results achieved from testing the different sizes.

Table VI: Effect of variable feed top size on UX7 performance

Size Fraction	Conc (A-E)			Tails (F-H)		
	Mass Yield	Grade %Cr_2O_3	Recovery	Mass Yield	Grade %Cr_2O_3	Recovery
-75+0µm	9.55	13.29	10.23	90.45	12.32	89.77
-106+0µm	9.66	17.05	12.65	90.34	12.6	87.35
-150+0µm	13.72	14.68	15.63	86.28	12.61	84.37
-300+0µm	19.04	18.13	25.52	80.96	12.40	74.48
-425+0µm	59.7	19.62	69.15	40.3	12.97	30.85

The results show that the coarser the material, the higher the mass yield and recovery of the chromite material. The mass yield ranged from 9 to 59% from the finest to the coarsest size fraction. It is worth noting that the samples were not deslimed prior to processing on the spiral.

Effect of Slimes

Table VII summarises the results achieved when processing material with slimes (undeslimed) and material where the slimes are removed/minimised (deslimed). The feed grade of the undeslimed material was 16.95% Cr_2O_3, while the deslimed material had a feed grade of 19.82% Cr_2O_3.

Table VII: Effect of slimes

Product	Undeslimed Material (-425+0 µm)					Deslimed Material (-425+10 µm)				
	Mass yield	Grade (%)		Recovery (%)		Mass yield	Grade (%)		Recovery (%)	
Split	(%)	Cr_2O_3	SiO_2	Cr_2O_3	SiO_2	%	Cr_2O_3	SiO_2	Cr_2O_3	SiO_2
Conc	59,71	19,62	30,1	69,15	54,38	79,52	21,53	29,54	86,35	75,42
Tails	40,29	12,97	37,43	30,85	45,62	20,48	13,21	37,38	13,65	24,58

The deslimed material showed a better mass yield and recovery than the material with slimes. The mass yield and recovery difference were 20% and 17% higher respectively on the deslimed material. The deslimed material had a chromite concentrate which was approximately 2% higher than the material with slimes, this can be attributed to a higher feed grade because of desliming before the spirals. Figure 9 graphically illustrates the relationship between the mass yield, grade, and recovery for the undeslimed and deslimed feed material.

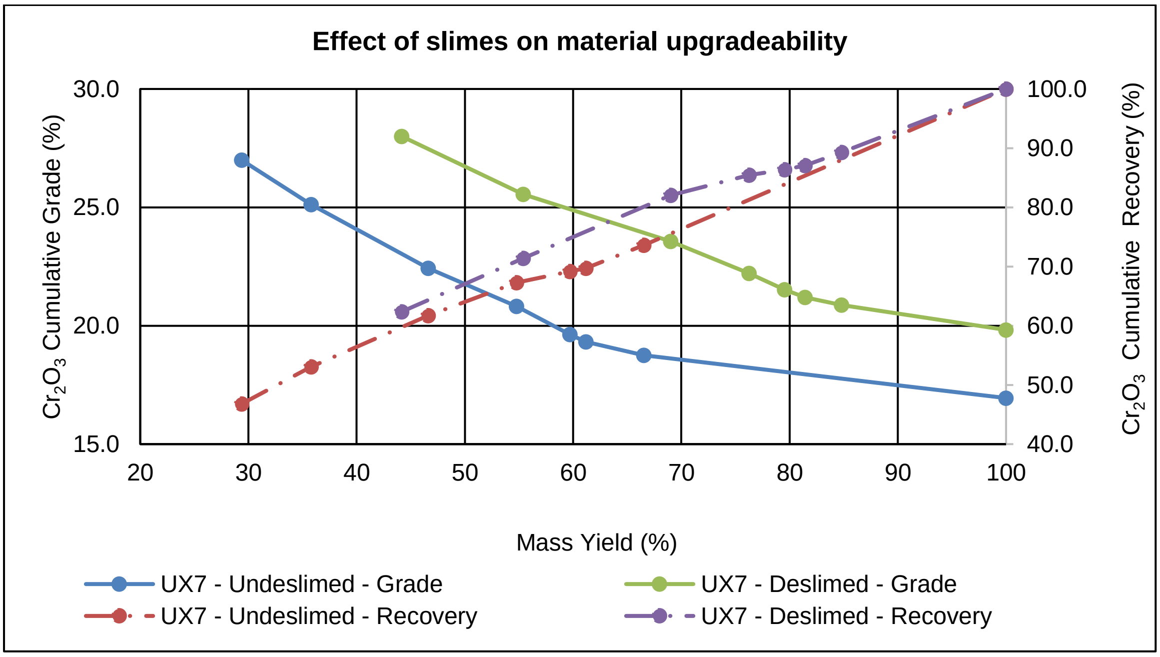

Figure 9: Effect of slime on material upgradeability

It is evident that the deslimed material showed superiority over the undeslimed material as it was consistently achieving higher grades across the mass yield range. The recoveries of the deslimed material were higher between 50%-80% mass yield in comparison to the undeslimed material.

Slimes removal was found to be beneficial as the feed material already gets an upgrade as seen at 100% cumulative mass yield that the deslimed material has a higher feed grade than the undeslimed material.

Effect of solids concentration

Figure 10 shows the relationship of the feed solids concentration and %Cr_2O_3 recovery to the concentrate stream on the UX7 spiral.

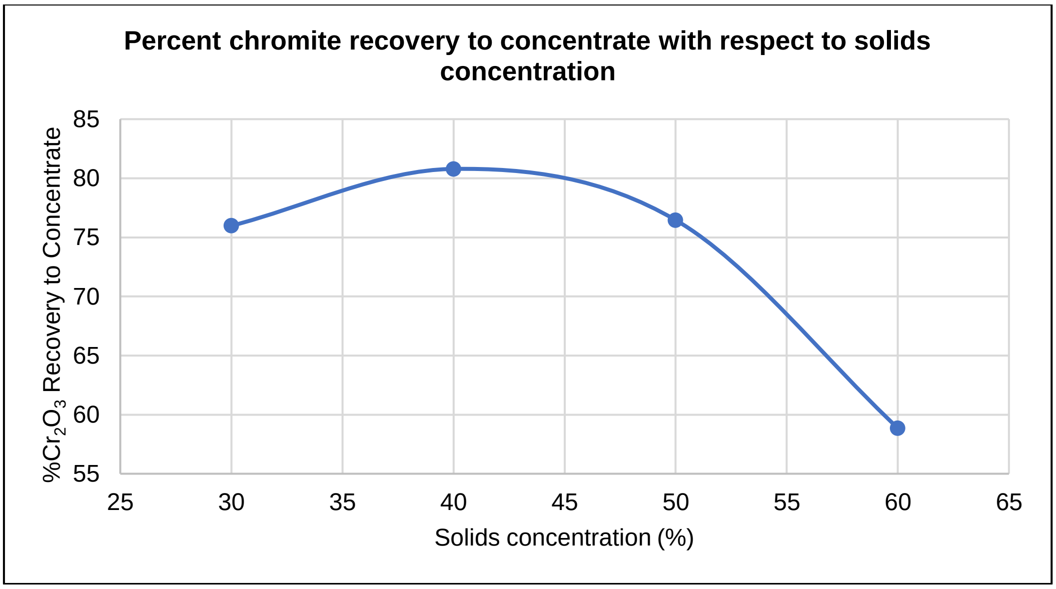

Figure 10: Solids feed concentration versus concentrate recovery on the UX7 spiral

The results show that the %Cr_2O_3 recovery increases with an increase in solid concentration until an optimum point is reached and beyond the optimum point the recovery decreases with a further increase in solid concentration. The optimal solid concentration for the UX7 was found to be at 40% solid concentration.

This was because when the material loading becomes concentrated the viscosity effect begins to take place and hinders efficient separation.

Effect of feed rate
Figure 11 illustrates a relationship between throughput and %Cr_2O_3 recovery to the concentrate stream on the UX7 spiral at 50% mass yield.

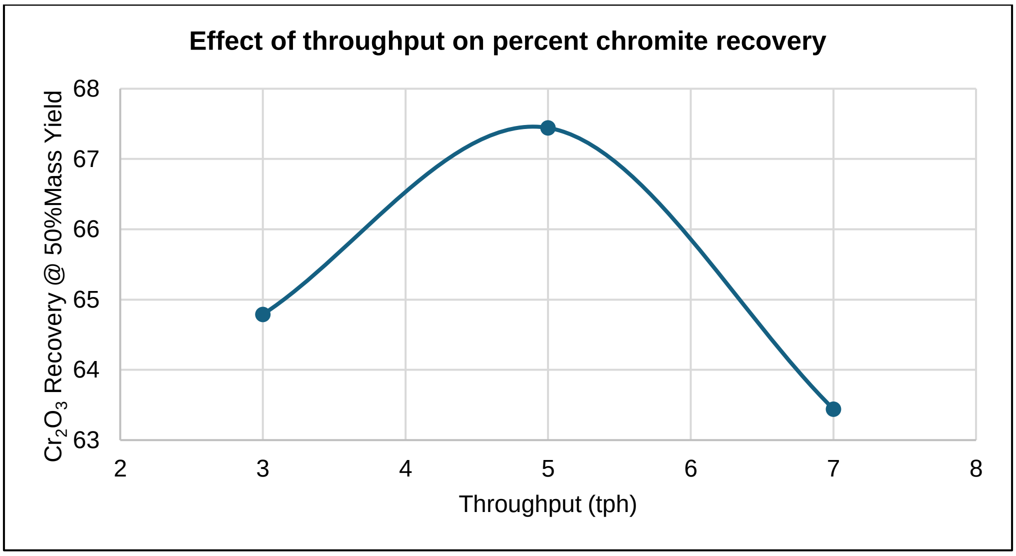

Figure 11: Effect of throughput on recovery

The results showed that the Cr_2O_3 recovery was increasing with an increase in dry solids throughput until an optimum point was reached, beyond the optimum point the recovery decreased with a further increase in dry solids throughput. It was found that the UX7 spiral has an optimal operating dry solids throughput at 5 tph.

Conclusion

The study investigated the metallurgical performance of the new UX7 spiral. The HX5 and the UX7 were tested, and performance compared. Various operational parameters were also tested to evaluate the effect on grade, mass yield, and recovery. The following were investigated: The effect of particle size, which was also done to establish the maximum top size on the UX7 spiral that does not cause beaching, the effect of slimes, the effect of solids concentration, and the effect of feed rate.

The HX5 and the UX7 spirals were compared using the material with a top size of 425 µm and 75 µm. The -425 µm material had a feed grade of 18 %Cr_2O_3 while the -75 µm had a feed grade of 13 %Cr_2O_3. At a 40% mass yield, The UX7 produced a concentrate with 28,03% Cr_2O_3 grade at a recovery of 62.28 %, the HX5 produced a concentrate with 27.67% Cr_2O_3 grade at a recovery of 61.49 %. The HX5 and UX7 at 425 µm size fraction showed no significant difference in concentrate grades and recoveries achievable. For the finer fraction, the UX7 spiral showed a 9% higher mass yield and 13% higher recovery than the HX5 spiral. The results from the two size fractions indicate that the UX7 can improve mass yield and recovery with the improvements being higher for the finer size material.

Material with various top sizes were tested, the various samples tested had a P100 of 75 µm,106 µm,150 µm, 300 µm and 425 µm. The corresponding P80 points of these samples varied between 27 and 111 µm. For the various feed top sizes, there was no beaching evident on the UX7 spiral, the material was observed to move smoothly without any build-ups.

Desliming the material before processing on spirals resulted in improvements in the spiral performance. The deslimed material showed a better mass yield and recovery than the material with slimes. The mass yield and recovery difference were 20% and 17% higher respectively on the deslimed material. The deslimed material had a chromite concentrate which was approximately 2% higher than the material with slimes.

The optimal solid concentration for the UX7 was found to be at 40% solid concentration by weight. The results show that the Cr_2O_3 recovery increases with an increase in solid concentration until an optimum point is reached and beyond the optimum point the recovery decreases with a further increase in solid concentration.

The optimal feed rate of the UX7 was found to be at 5tph. The results showed that the Cr_2O_3 recovery was increasing with an increase in dry solids throughput until an optimum point was reached, beyond the optimum point the recovery decreased with a further increase in dry solids throughput.

The outcome of this study shows that the UX7 spiral can be used to achieve improvements in both mass yield and recovery while processing fine material. The increase in mass yield and recovery was shown to be more significant for the ultra-fine material. The feed rate and feed solids concentration on spirals play a vital role in the overall performance. The optimal feed rate and solid concentration on the UX7 were found to be 5tph and 40% solid concentration by weight. Desliming the material before processing on spirals resulted in improvements in grade, mass yield, and recovery, although caution needs to be exercised to avoid losing more fines desliming at a cut point of 10 µm is recommended.

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