THE EFFECT OF REPULPING ON THE SX7 SPIRAL

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ABSTRACT

Spirals concentrators are widely used for beneficiation of fine coal typically the -1mm size fraction. The repulper and the splitter on the SX7 spiral play a vital role in determining the final product ash. The splitter separates the material after the 3rd turn into two streams; high ash and low ash streams. The high ash stream is channeled into the center column while the low ash is directed into the repulper. The material in the center column is collected at the end of the spiral trough as a reject fraction. The low ash fraction on the other hand is mixed again in the repulper and given a second chance for further rejection of ash.

The aim of the study was to evaluate the metallurgical performance of the new SX7 spiral with a drop-in repulper design. Three models of the SX7 spirals were tested and compared, the SX7 without a repulper, the SX7 with the old repulper design and the new SX7 with a drop-in repulper design. The spiral without repulper was tested to provide a benchmark against which the spirals with the different repulper designs were compared; all spirals were tested at 25%, 30% and 35% solid concentration. The solid feedrate was kept constant around 3tph. The product samples were analyzed for ash and calorific value (CV).

The findings consistently show that there are no differences in Ash and CV contents achieved in the concentrate fractions on both spirals at various solid concentrations. The mass yield on the old spiral is however higher than on the new spiral, at the same splitter setting for all the tests at various solid concentrations. This could possibly be explained by the fact that on the old SX7 spiral, a gap is created between the bottom of the splitter and the trough floor and allows the material to seep through to the repulper. This furthermore suggests that there is room on the new spiral for the splitter position to be slightly closed to allow more material to go through the repulper section to obtain more mass yield without increasing the concentrate ash.

The results show that the modifications done on the new SX7 spiral have not negatively affected the metallurgical performance of the spiral. The new SX7 spiral with a drop in repulper allows for replacement of the repulper and the lid when worn out. The spiral has a fixed hollow area where the repulper fits; this is expected to eliminate the inconsistencies as a result of variability in assembly. The new lid does not compress the edge rubber and as a result spillages are eliminated. On the new spiral, the material bypass has been eliminated, the shape of the splitter follows the trough profile, the floor of the spiral where the splitter sits has been made to ensure that the splitter sits flat on the spiral trough and does not create a gap. The splitter is also longer than on the old spiral, this is expected to provide flexibility to open the splitter wider to only direct a narrow stream to the repulper if a lower ash product is required.

INTRODUCTION

Spirals concentrators are process equipment used for beneficiation of minerals. Spirals separate valuable minerals from gangue on the basis of their density. Among the gravity separators, the spiral concentrator is considered to be one of the most efficient and simple unit operations. Because of its relative simplicity and high efficiency, it is widely used under a variety of circuit configurations for processing of minerals and coals (Das et al., 2007).

The market has various product specifications in terms of ash, i.e, thermal and coking coal grades. The repulper and the splitter on the SX7 spiral play a vital role in determining the final product ash. The splitter separates the material after the 3rd turn into two streams; high ash and low ash streams. The high ash stream is channeled into the center column while the low ash is directed into the repulper. The material in the center column is collected at the end of the spiral trough as a reject fraction. The low ash fraction on the other hand is mixed again in the repulper and given a second chance for further rejection of ash.

The performance of the coal-processing spiral is a critical function of its design parameters, which include diameter, height, number of turns, pitch, slope, shape of the trough and its dimension. Holtham (1992) found the flow can be considered to be fully developed after at most two turns. Studies have also shown that feed rate, especially the total volumetric flow greatly affects its performance and is among one of the critical factors for determining coal spiral capacity. Investigations (Holland-Batt, 1995) show that, for any feed pulp density there exists an optimum feed rate. Studies (MacNamara et al., 1995) indicate that the spiral performance is considerably affected by slurry density and that a more dominant control is observed when combining the slurry with the solid flow rate. Based on a typical coal cleaning application, spirals effectively treat between 2 and 3 t/h per start at a recommended solid concentration of 30% by weight (Osborne, 1986).

When separation is in progress on the spiral, the heavy particles migrate toward the inner region of the trough, the concentration of these dense particles becomes high and as a result the ease of flow of material becomes reduced. This bed of particles in a wash waterless spiral can prevent further separation of particles. This necessitates the use of splitters to remove the material that has already separated from the trough before they start to beach. Continuous removal of the concentrate along the length of the spiral provides more area for further separation. The reduced fluidity in the inner region of the trough can be restored by employing repulpers. Repulpers spray back the dilute material from the outside of the trough in a shallow fan over the inner part of the trough. This also provides the misplaced heavy mineral on the outside of the trough with another chance of separation. Removal of product followed by employing a repulper to spray back the dilute material from the outside of the trough over the inner part of the trough was shown to be effective in restoring the initial higher rate of recovery. The efficiency at the same mass take by 5-6% and similar gains have been recorded on many other spirals and feed types. Repulpers are however considered to be counter-productive on the coal spiral they decrease the recovery of coal. The repulping action is said to be detrimental to recovery since coal is less dense and it concentrates on the outside of the trough, spraying back dilute material from the outside of the trough results in relocation of the already separated coal product to the reject stream (Holland-Batt, 1995). Contrary to the above findings, studies with a repulper used as a mixing box on the SX7 spiral has been shown to enhance a product grade of coal, the use of the repulper in this case enabled a single spiral start to be utilized as a spiral that does both primary and secondary stages (Prinsloo & Abela, 1998).

The inside of the repulper due to the mixing that occurs inside is characterized as a high wear area. With the current design of the repulper on the SX7, the repulper lid and the wear pad of the repulper are the components that are prone to wearing quicker than the entire spiral. This wear pattern shortens the life of the spiral since the wear pad and the lid cannot be replaced without replacing the spiral. The mixing channels on the current design are positioned on the lid of the repulper, during assembly the positioning is also a challenge, this causes a lot of problems which contributes to splashing of water and buildup of material on the inside of the repulper.

To obtain a product with lower ash the SX7 spiral is required to have a flexible splitter that can be positioned differently to accommodate various product specifications. For a lower ash product requirement like coking coal product, depending on the feed grade the splitters may need to be opened wider. The current splitter size on the SX7 is short, opening the splitter wider creates a gap between the splitter and the spiral trough, and this is believed to be due to the profile change towards the outside of the spiral. The profile of the spiral is flatter towards the outside; the gap between the splitter and the spiral trough causes the high ash material to seep through to the clean coal and increases the ash content to the secondary cleaning, this results in the higher than expected ash in the product. The current design which is flat promotes buildup of the material on the splitter.

The aim of the study was to evaluate the metallurgical performance of the new SX7 spiral with a drop-in repulper design. The improvements are not expected to negatively affect the metallurgical performance of the new SX7 spiral. The expectation is that the new spiral should provide similar upgrades to the old spiral if not better. The new SX7 spiral design allows for replacement of a repulper and the lid when worn out. The spiral has a fixed hollow area where the repulper fits; this is expected to eliminate the inconsistencies as a result of variability in assembly. The new lid does not compress the edge rubber and as a result spillages are eliminated. The use of longer splitters, which allows the splitter to be opened wider with reference to the center column, and the modification to eliminate the material bypass, is expected to provide the flexibility to produce lower ash product than with the use of the shorter splitter. These modifications are expected to enhance the SX7‘s robustness in processing the material with various product ash specifications.

BACKGROUND

The increased fine coal production caused by the use of mechanized mining and communition has led to increased attention being given to the beneficiation of fine coal since the material is of economic value. The -0.5mm material has been reported as being 15% of most South African ROM material (England et al., 2002). The most common processes available for fine coal are spirals, flotation, dense medium separation (DMS) and water only cyclones. Spirals are primarily used for cleaning coal in the intermediate size range of 100µm to 2000µm. These coal particles are neither large enough for heavy media separation and nor small enough for froth flotation (Kapur & Meloy, 1999). Figure 1 shows a particle size versus efficiency curve for various coal processing options.

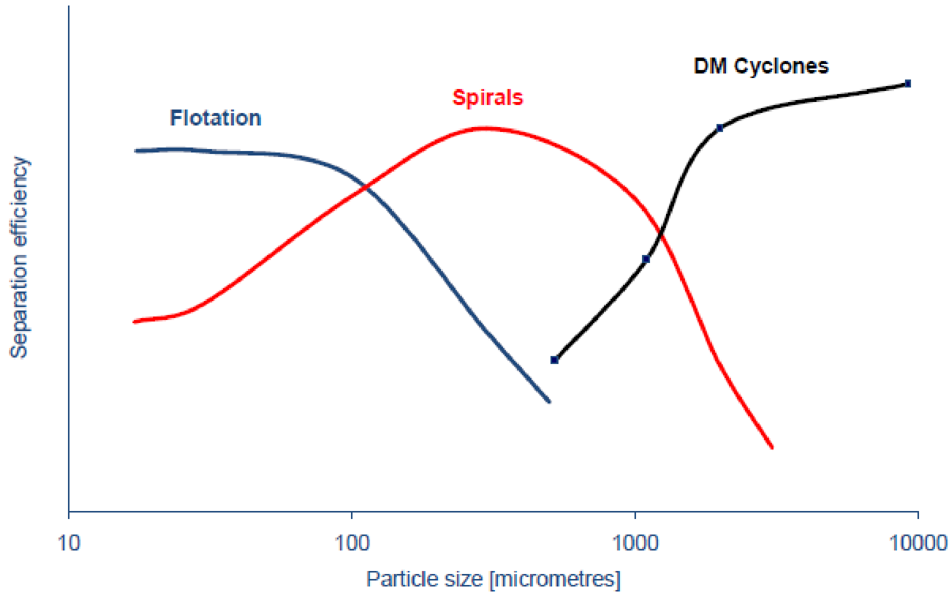

Figure 1: Particle size versus separation efficiency

Spirals exhibit one of the most complex flow regimes among gravity separators. Spiral concentrator flows display laminar to increasingly turbulent behavior. The primary flow is that of the slurry descending the inclined portion of the trough. Secondary flow occurs radially across the trough. During their passage through a spiral, particles are subjected to hydrodynamic drag and lift, friction, gravity and centrifugal forces.

Figure 2 shows the forces a particle are exposed to while travelling down the spiral trough.

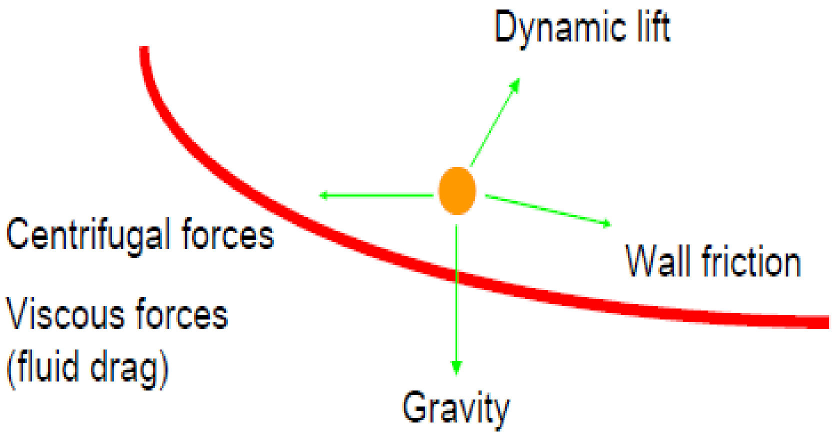

Figure 2: Forces on a particle while in motion

The first coal spirals were developed in 1945 by Humphreys (Thompson & Welker, 1990) and these units had six turns operating within approximately the same height as the five turn mineral spirals developed previously. Shorter length spirals are more effective in the separation of coarse particles while longer spirals are necessary for the concentration of smaller particles. Therefore different length spirals should be utilized with respect to size distribution of coal in order to achieve a more effective separation. (Atasoy & Spottiswood, 1995). It has been claimed that effective separation is at an end after 2 turns on mineral spirals (Yashin et al., 1984), while another viewpoint suggests that after 2 turns the rate of recovery on coal spirals has fallen to the point where a revitalization of the separation is needed (Edward et al., 1993).

The adoption of a repulper following the auxiliary splitter increases the efficiency at the same mass take by 5-6% and similar gains have been recorded on many other spirals and feed types. In considering the role of repulpers, there are also significant differences between mineral and coal spirals. On a mineral spiral, the repulping action adds additional solids and water to the concentrate zone thereby potentially improving the recovery, while on a coal spiral the action of the repulper relocates slurry from the coal product to the refuse zone, which in the short term at least must decrease the recovery of coal (Holland-Batt, 1995). Contrary to the above findings, studies with a repulper used as a mixing box on the SX7 spiral has been shown to enhance a product grade of coal, the use of the repulper in this case enabled a single spiral start to be utilized as a spiral that does both primary and secondary stages (Prinsloo and Abela, 1998).

EXPERIMENTAL

The aim of the study was to evaluate the efficacy of the new SX7 spiral with a drop-in repulper design. Three models of the SX7 spirals were tested and compared, the SX7 without a repulper, the SX7 with the old repulper design and the new SX7 with a drop-in repulper design. The spiral without repulper was tested to provide a benchmark against which the spirals with the different repulper designs were compared; all spirals were tested at 25%, 30% and 35% solid concentration. The solid feed rate was kept constant around 3tph.The splitter on the spirals was also kept constant at 240mm with reference to the center column. The product samples were analyzed for ash and calorific value (CV).

Equipment description

The coal spiral has a relatively small axial and radial inclination, which implies that the outward centrifugal force is always limited. As a result, the bulk of the relatively heavy soil moves to the inner rim while light, organic contaminants concentrate away from the inner rim (Glass et al., 1999). Figure 3 shows the SX7 spiral. The SX7 is a 7 turn spiral, 1000mm in diameter and has a pitch of 13°.

Figure 3: SX7 spiral

The spiral is equipped with a repulper, which is positioned after the 3rd turn of the spiral. The splitter separates the material after the 3rd turn into two streams; high ash and low ash streams. The high ash stream is channeled into the center column while the low ash is directed into the repulper. The material in the center column is collected at the end of the spiral trough as a reject fraction. The low ash fraction on the other hand is mixed again in the repulper and given a second chance for further rejection of ash. Table 1 shows typical operating data of the SX7 spiral.

Table 1: Operating range for the SX7 spiral

Coal spiral			Primary duty
Solids dry tonnage	tph	Max	3.2
	tph	Min	1.0
Volumetric flow rate	m^3/hr	Max	13.5
	m^3/hr	Min	7.6
Particle size	µm	Max	2000
	µm	Min	106
Feed % solids	%	Max	35
	%	Min	25

Table 2 shows the test plan used and a summary of results obtained.

Table 2: Test Plan and Summary of Results

	Test Parameters			Recon Feed Grade		Concentrate	Concentrate Grade		Concentrate Recovery	
Test	**% Solid concentration**	**Orifice**	**Solid feed rate tph**	**CV,MJ/Kg**	**% Ash**	**% Mass yield**	**CV,MJ/Kg**	**% Ash**	**CV,MJ/Kg**	**% Ash**
SX7 WITH OLD REPULPER										
1	25	40	3	16.76	44.69	55.96	23.64	24.00	78.95	30.05
2	25	40	3	18.96	39.15	60.74	24.05	23.30	77.06	36.15
Ave	25	40	3	17.86	41.92	58.35	23.85	23.65	78.00	33.10
3	30	35	3	18.44	39.19	60.55	23.60	23.90	77.51	36.92
4	30	35	3	19.59	37.68	62.35	24.90	21.40	79.24	35.41
5	30	35	3	17.66	42.45	58.46	23.50	25.30	77.81	34.84
Ave	**30**	**35**	**3**	**18.56**	**39.78**	**60.45**	**24.00**	**23.53**	**78.18**	**35.72**
6	35	30	3	16.82	43.24	51.87	23.86	21.90	73.60	26.30
7	35	30	3	18.24	40.21	57.00	24.00	23.20	75.00	32.90
8	35	30	3	18.65	38.94	56.40	24.54	21.60	15.71	6.18
Ave	**35**	**30**	**3**	**17.90**	**40.79**	**55.09**	**24.13**	**22.23**	**54.77**	**21.79**
SX7 WITH NEW REPULPER										
1	25	40	3	17.87	40.97	53.55	23.86	23.30	71.50	30.45
2	25	40	3	18.03	40.14	54.51	23.40	24.40	70.74	33.13
3	25	40	3	17.93	40.45	53.42	23.74	23.50	70.74	31.03
Ave	**25**	**40**	**3**	**17.94**	**40.52**	**53.83**	**23.67**	**23.73**	**70.99**	**31.54**
3	30	35	3	17.12	42.95	50.64	23.85	23.20	70.54	27.36
4	30	35	3	18.04	40.34	54.37	23.98	23.00	72.26	31.00
Ave	**30**	**35**	**3**	**17.58**	**41.65**	**52.51**	**23.92**	**23.10**	**71.40**	**29.18**
6	35	30	3	18.14	40.21	49.29	24.42	22.10	66.34	27.09
7	35	30	3	18.08	40.50	48.56	24.94	20.90	66.99	25.06
8	35	30	3	18.04	40.28	47.33	24.30	22.20	63.77	26.09
Ave	**35**	**30**	**3**	**18.09**	**40.33**	**48.40**	**24.55**	**21.73**	**65.70**	**26.08**

RESULTS AND DISCUSSION

Figure 4 shows a comparison of the average cumulative grade/yield results for all the spirals at 25% solid concentration.

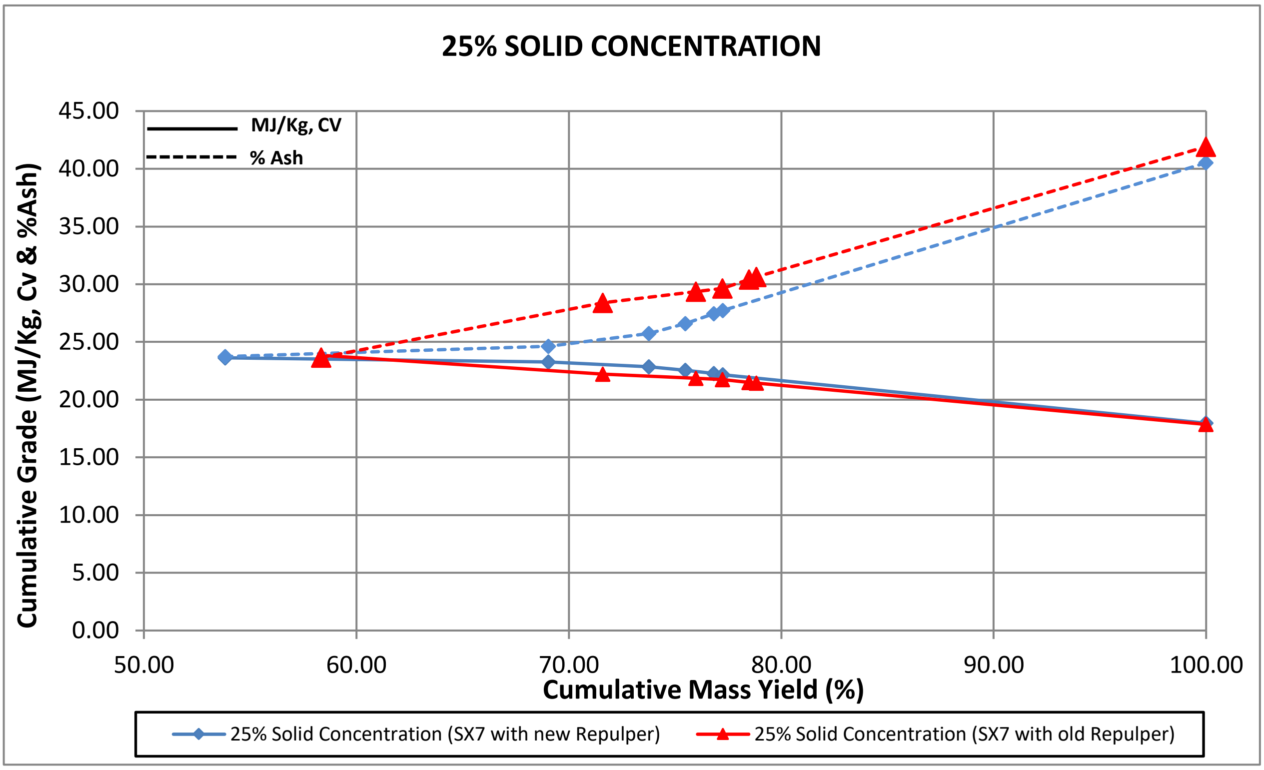

Figure 4: Cumulative grade and mass yield at 25% solid concentration

The calorific value on the old SX7 was upgraded from 17.86MJ/kg in the feed to 23.85 MJ/kg in the concentrate. The Ash content was reduced from 41.92% in the feed to 23.65% in the concentrate. This was achieved at a mass yield of 58.35%

The calorific value on the new SX7 was upgraded from 17.94MJ/kg in the feed to 23.63 MJ/kg in the concentrate. The Ash content was reduced from 40.82% in the feed to 23.73% in the concentrate. This was achieved at a mass yield of 53.83%.

The CV and Ash in the concentrate obtained on both spirals are similar at 25% solid concentration, there is however a difference of about 4.52% in mass yield. The old SX7 spiral showed higher mass yield at the same splitter setting.

Figure 5 shows a comparison of the average cumulative grade/ yield results for all the spirals at 30% solid concentration.

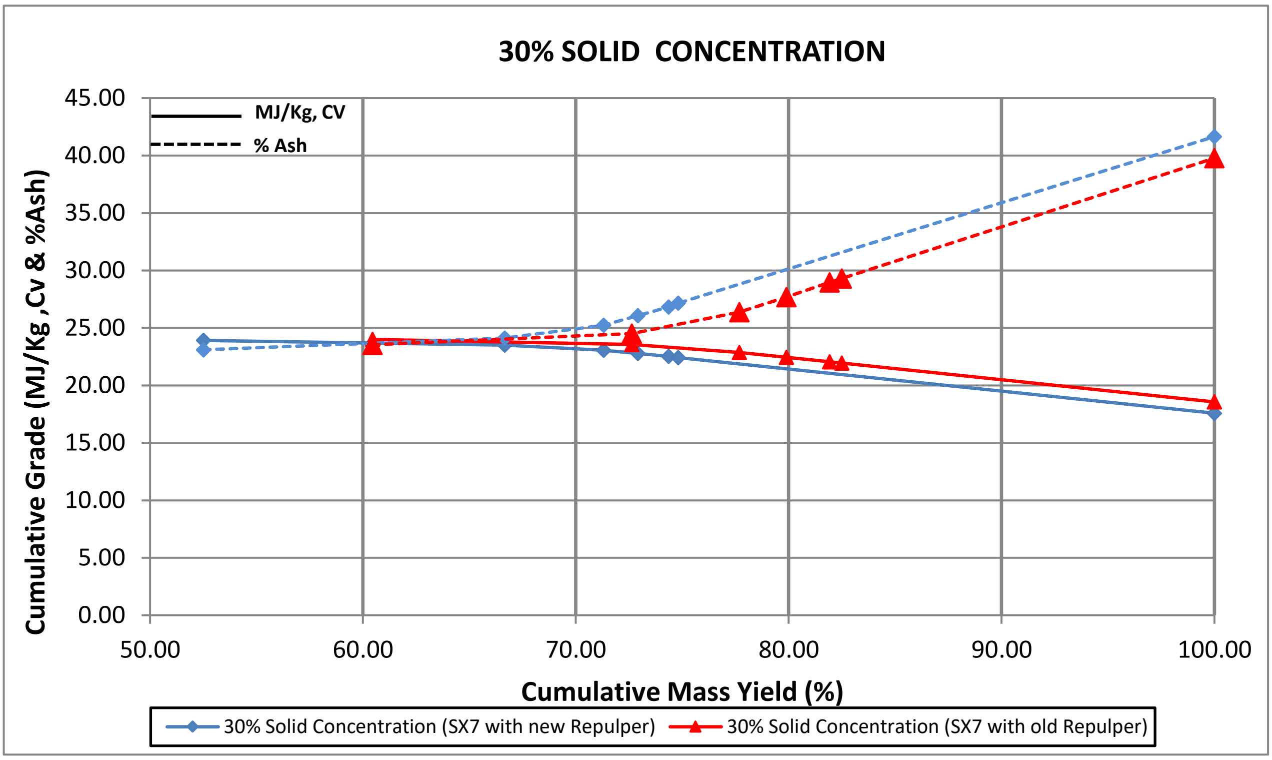

Figure 5: Cumulative grade and mass yield at 30% solid concentration

The calorific value on the old SX7 was upgraded from 18.56 MJ/kg in the feed to 24.00 MJ/kg in the concentrate. The Ash content was reduced from 39.77% in the feed to 23.53% in the concentrate. This was achieved at a mass yield of 60.45%

The calorific value on the New SX7 was upgraded from 17.58 MJ/kg in the feed to 23.92 MJ/kg in the concentrate. The Ash content was reduced from 41.65% in the feed to 23.10% in the concentrate. This was achieved at a mass yield of 52.51%

The CV and Ash in the concentrate obtained on both spirals are similar at 30% solid concentration, there is however a difference of about 7.94% in mass yield. The old SX7 spiral showed higher mass yield at the same splitter setting.

Figure 6 shows a comparison of the average cumulative grade/ yield results for all the spirals at 35% solid concentration.

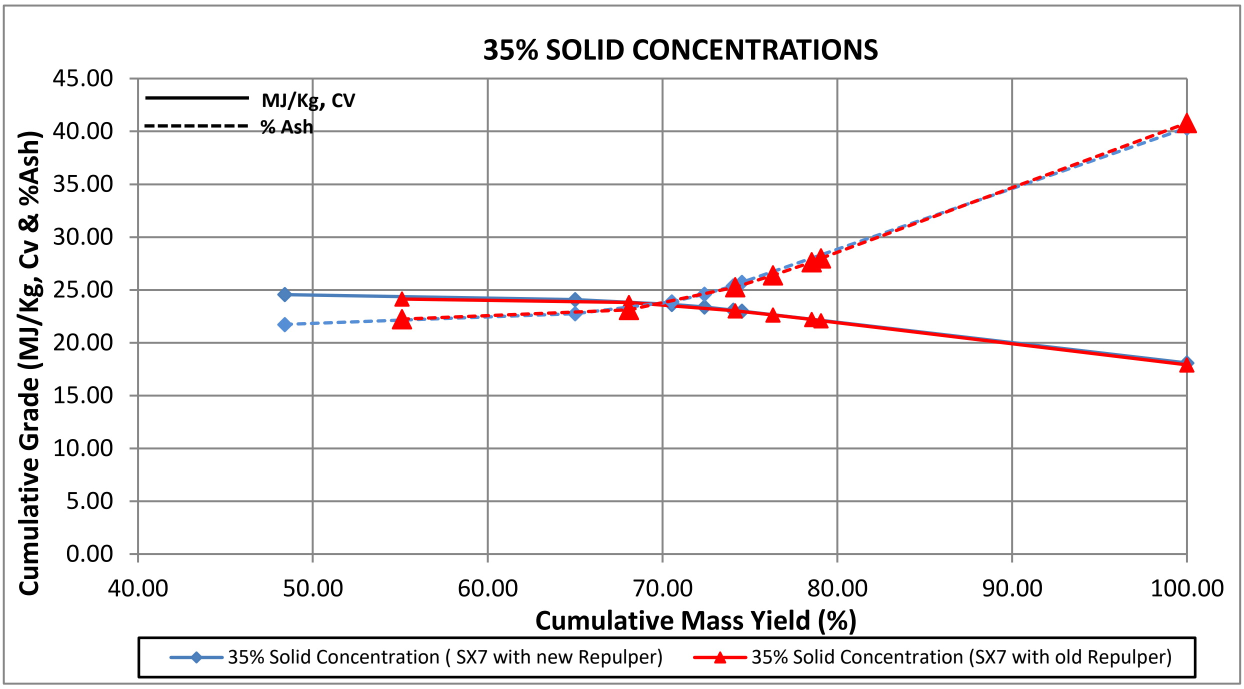

Figure 6: Cumulative grade and mass yield at 35 % solid concentration

The calorific value on the old SX7 was upgraded from 17.90MJ/kg in the feed to 24.13 MJ/kg in the concentrate. The Ash content was reduced from 40.80% in the feed to 22.23% in the concentrate. This was achieved at a mass yield of 55.09%

The calorific value on the new SX7 was upgraded from 18.09 MJ/kg in the feed to 24.55 MJ/kg in the concentrate. The Ash content was reduced from 40.33% in the feed to 21.73% in the concentrate. This was achieved at a mass yield of 48.40%.

The CV and Ash in the concentrate obtained on both spirals are similar at 35% solid concentration, there is however a difference of about 6.69% in mass yield. The old SX7 spiral showed higher mass yield at the same splitter setting.

The CV and Ash in the concentrate obtained on both spirals are similar at 25%, 30% and 35% solid concentration, this suggest that the modifications on the new spiral do not affect the metallurgical performance of the spiral negatively. The mass yield on the old spiral is however higher than on the new spiral, at the same splitter setting for all the tests at various solid concentrations. This could possibly be explained by the fact that on the old SX7 spiral, the splitter creates a gap at the bottom and allows the material to seep through to the repulper.

CONCLUSIONS

The study investigated the metallurgical performance of the new SX7 spiral with a drop-in repulper design. The old and the new SX7 were tested and performance compared.

The findings consistently show that there are no differences in Ash and CV contents achieved in the concentrate fractions on both spirals at various solid concentrations. At 25% solid concentration, the calorific value on the old SX7 was upgraded from 17.86 MJ/kg in the feed to 23.85 MJ/kg in the concentrate. The Ash content was reduced from 41.92% in the feed to 23.65% in the concentrate. This was achieved at a mass yield of 58.35%. Furthermore the calorific value on the new SX7 was upgraded from 17.94 MJ/kg in the feed to 23.63 MJ/kg in the concentrate. The Ash content was reduced from 40.82% in the feed to 23.73% in the concentrate. This was achieved at a mass yield of 53.83%.

At 30% solid concentration, the calorific value on the old SX7 was upgraded from 18.56 MJ/kg in the feed to 24.00 MJ/kg in the concentrate. The Ash content was reduced from 39.77% in the feed to 23.53% in the concentrate. This was achieved at a mass yield of 60.45%. On the other hand, the calorific value on the New SX7 was upgraded from 17.58 MJ/kg in the feed to 23.92 MJ/kg in the concentrate. The Ash content was reduced from 41.65% in the feed to 23.10% in the concentrate. This was achieved at a mass yield of 52.51%.

At 35% solid concentration, the calorific value on the old SX7 was upgraded from 17.90MJ/kg in the feed to 24.13 MJ/kg in the concentrate. The Ash content was reduced from 40.80% in the feed to 22.23% in the concentrate. This was achieved at a mass yield of 55.09%. The calorific value on the new SX7 was upgraded from 18.09 MJ/kg in the feed to 24.55 MJ/kg in the concentrate. The Ash content was reduced from 40.33% in the feed to 21.73% in the concentrate. This was achieved at a mass yield of 48.40%.

The mass yield on the old spiral is however higher than on the new spiral, at the same splitter setting for all the tests at various solid concentrations. This could possibly be explained by the fact that on the old SX7 spiral, the splitter creates a gap at the bottom and allows the material to seep through to the repulper. This furthermore suggests that there is room on the new spiral for the splitter position to be slightly closed to allow more material to go through the repulper section to obtain more mass yield without increasing the concentrate ash.

The results show that the modifications done on the new SX7 spiral have not negatively affected the metallurgical performance of the spiral. The new SX7 spiral with a drop in repulper allows for replacement of the repulper and the lid when worn out. The spiral has a fixed hollow area where the repulper fits; this is expected to eliminate the inconsistencies as a result of variability in assembly. The new lid does not compress the edge rubber and as a result spillages are eliminated. On the new spiral, the material bypass has been eliminated, the shape of the splitter follows the trough profile, the floor of the spiral where the splitter sits has been made to ensure that the splitter sits flat on the spiral trough and does not create a gap. The splitter is also longer than on the old spiral, this is expected to provide flexibility to open the splitter wider to only direct a narrow stream to the repulper if a lower ash product is required.

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