QUALITY IMPROVEMENTS FOR SOUTH AFRICAN COAL FINES BY FLOTATION WITH MONTENOL AND AGGLOMERATION.

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ABSTRACT

Coal is an important fossil fuel and as a source of energy for South Africa and globally. Fine coal has been since an unattractive product because of problems associated but not limited to handling and transportation. With the depreciation of coal quality, better coal products are reserved for the export market leaving the poor quality coal products for domestic electricity generation. Based on the latter, this has resulted in interest and advancement in the coal processing techniques and progressive technologies. With these recent developments, fines can be processed, prepared and sold for profit. The current work focused of flotation of discards with the aim to upgrade the quality of coal. Flotation with Montenol 800 and 505 produced a clean coal product with high ash reduction with a very good combustibles recovery after 30 and 35 minutes milling of the fine coal sample, but this has proven to be over milling as coal is soft. This is supported by the sampled milled for only one minute where there was consistency over 40% separation efficiency over all different times employed. The ash rejections were over 40% and 45% for Montenol 505 and 800 respectively with the very high combustible recovery higher than 95% for Montenol 505. The results showed that fine coal cleaning using Montenol is possible to increase the quality of coal. The sample was further agglomerated using different binders; all binders considered yielded bigger pellets with only a small fraction of particles that were less than 5mm. In addition, it was found that the final product was of a better quality in terms of reduced moisture, CV and ash content.

Key words: ash rejection, fine coal, flotation, upgrade, agglomeration.

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1. INTRODUCTION

Coal is made up of two main groups of materials namely the organic matter and the inorganic matter. The organic matter also called maceral components are the part defining coal and its value in different utilization processes, and the inorganic matter also called mineral matter does not have any good contribute to the value and utilization of coal; it is however associated with the negative behaviour of coal during the utilisation of coal (Ward 2002). South African coals are mostly of low quality with a significant amount of incombustible mineral matter. They are typically medium rank C bituminous coals rich in inertinite and contain high mineral matter content (Malumbazo, Wagner, and Bunt 2012).

South Africa is not just one of the world's top coal producers but also a major coal consumer mainly by power generation consuming more than 46% of produced coal nationwide (Steyn and Minnitt 2010), followed by metallurgical industries and synthetic fuel industry (Hancox and Götz 2014) (Tshiongo and Mulaba-bafubiandi 2013)(Steyn et al. 2011). Advantages of coal for electricity generations includes the fact that coal is cheap, reliable, and abundant. Eskom is the state owned national utility that dominates South Africa' s power industry with a production of more than 95% of the country electricity demands. (Hancox and Götz 2014)(De Korte, 2013) (Steyn and Minnitt 2010). At the current time, Eskom has 13 pulverised coal fired power stations around the country consuming 110 million metric tons of coal produced in a year (Wiid et al., n.d.)(Steyn and Minnitt 2010).

Globally coal resources are depleting and mining conditions are becoming complicated with the geological setting of the reserve determining characteristics of that specific coal. This has then affected the quality produces, where in the past coal was mined screened and sold to the customers but now washing and other upgrading is employed to increase on the quality produced. Coal quality for electricity generation has therefore been deteriorating as coal producers are reserving their better quality coals for export markets sold for a better profit (Wiid et al., n.d.).

Quality properties that have been on the decline includes the CV, Ash content, particle size distribution, abrasiveness index, Moisture content, Sulphur etc. (Wiid et al., n.d.)(Steyn and Minnitt 2010).Even though Eskom's power stations are suffering due to the decreased coal quality, this should not be dealt with by substituting with export coals but be dealt with by tighter contract management with coal producers.

Eskom imposes 30-50% penalties to the coal producer for the supplied coal that is in the rejection range in respect of qualities either than volatile matter (Steyn and Minnitt 2010). Because of the depletion in reserves and the produced low quality coal, Eskom cannot reject the coal supplied even though the quality variance falls outside the contractual limits due to the demands in electricity and deteriorating overall coal supply.

Coal production in South Africa is mainly through the DMS processes, where finer particles are not considered because of the challenges that are associated with handling and transportation of finer particles. DMS processes have higher separation efficiencies for courser particle sizes (Honaker, Kohmuench, and Luttrell 2013), whereas finer particles can be separated effectively by flotation method. Flotation is a physico-chemical separation process that utilises particle surface properties which is highly dependent on particle size (Qu et al. 2015)(Opperman, Nebbe, and Power 2002). Moreover, this is aided by addition of chemical reagents. Coal is naturally hydrophobic and make it easier to float (Laskowski 2013).

Coal fines are currently discarded as they are considered a waste product due to the low quality and the finer particle size that results in problems associated with handling and transportation. With this noted, it becomes very crucial for project such as the current with the aim to upgrade the quality of coal fine discards to sellable products with properties acceptable for utilization.

Agglomeration of coal is important in providing coal product that are of an acceptable particle size and strong enough to withstand handling and transportation from the producer to the user. Various properties like moisture content, hydrophobicity of the coal, binder effect have a determining factor on the pellet growth (Laskowski 2013).

2. EXPERIMENTAL

The spiral discards from a coal processing plant was used for this project and the flowsheet of the plant where the samples were taken is presented on figure 1. The sample considered was obtained in the spiral discards.

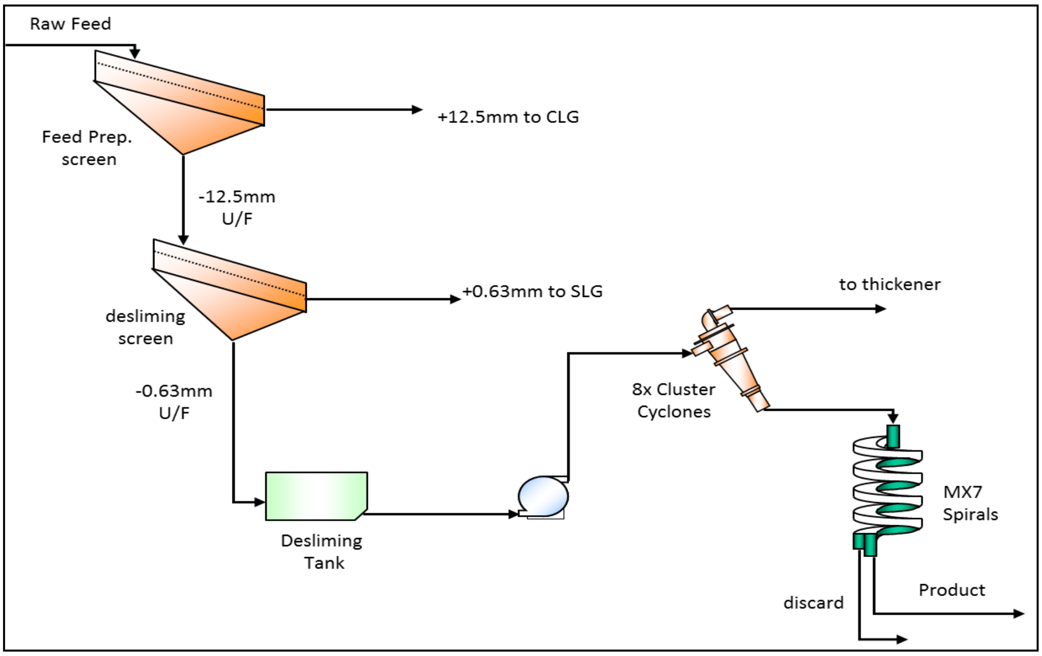

Figure 1: Flow diagram of the plant where the samples where obtained.

2.1 Proximate analysis

This was done before and after the experiments so that we can compare the improvements from the experiments performed. The test done were assessing the inherent moisture, volatile matter, CV, percentage ash and fixed carbon. The analyses were done on multiple samples and the results are tabulated on the results.

2.2 Grindability test

From the plant, a sample was separated using a spiral which gave the discard and product coal. The discard part was then split into two portions one of which was used for a grindability test in order to achieve 80% of the particles passing 212 µm. The different milling times experimented on are 10,20,30 and 35 minutes. And the other was the un-milled sample and both samples were prepared for the next batch of experiments.

2.3 Flotation

Prepared samples were used for flotation experiments using laboratory scale Denver cell. They were floated using two different Montenol reagents (800 and 505). The parameters investigated includes the flotation reagents dosage, duration of flotation and the effect of grinding time on the efficiency of the flotation process.

2.4 Agglomeration

A drum roller was used for the agglomeration process using different binders on the product upgraded by flotation. Compression strength analyses of pellets formed from different binders and the upgrade in terms of CV was conducted and the results are tabulated in the results.

3. RESULTS AND DISCUSSIONS

This section of the paper displays summarised results that were obtained from the different experiments that were conducted for this work.

3.1 Proximate analysis

Average results for the proximate analyses conducted on the feed sample is presented in Table 1. Although Eskom requires different coal qualities on their 13 coal fired power generations, the table only indicates the averages.

Table 1: Proximate analyses results obtained from the feed sample for the experimental work.

	Inherent moisture	**Volatile matter %**	**Ash %**	**CV(MJ/Kg)**
Feed sample	2,94	25,96	39,25	17,031
ESKOM requirements	10	>20	25- 33	21
ESKOM rejects	12	<20	>35	<20

Coal sample used as feed for this research had the acceptable volatile matter and moisture content, but the other quality properties that matter like the ash percentage and calorific values are way over the rejection limits. Coal spiral concentrators are designed for the product quality requirements. A higher percentage of the coal produced in South Africa is utilised for electricity generation, the spirals are designed to produce that quality. Separation in the spiral is done according density and particle size. Although this kind of separation has higher efficiencies, coal particles that are not well liberated will report to the discards. By evaluating the amount of volatile matter from the spiral discards it can be observed that upgrading the discards is a great idea.

3.2 Grindability test

In order to make sure that enough liberation is allowed for the coal feed, it is important to study the related grindability index. Results from the grindability test are shown in figure 2.

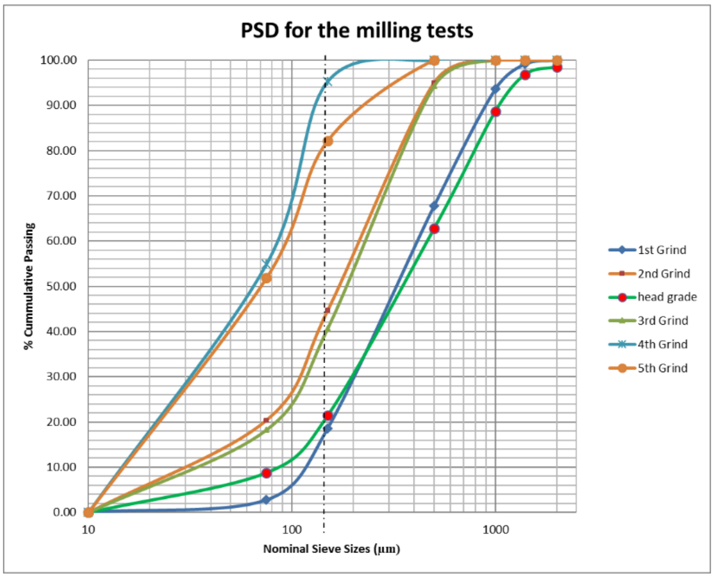

Figure 2:Grindability Test (original feed, 1, 10, 20, 30, 35 minutes) on Spiral discard head sample prior to the flotation tests.

Coal is naturally softer rock, but its grindability is highly affected by the mineral matter associated with the specific sample. This was considered for this work as the discards (high in mineral matter) sample was studied. From the grindability test, it was observed that grinding coal for more than 30 minutes resulted in more than 80% material passing through a 212µm as compared to just over 20% for the feed sample. From this results it can be observed that grindability of the coal considered is directly linked to the grinding time.

3.3 Flotation

Flotation at different reagents dosages was conducted, and the results are shown in Figure 3. The percentage of combustible recovery and mass yields increases with increased dosages for both Montenol 505 and 800, although Montenol 505 had the best results.

With over 50% for both mass yield and combustible recovery on all dosages, these indicates the higher feasibility of using the two reagents for using flotation as an upgrading method for coal spiral discards. Results were expected as the feed sample contained reasonable volatile matter percentages. It is also important to assess the quality components like percentage ash rejection and the improvement on the calorific value of the sample.

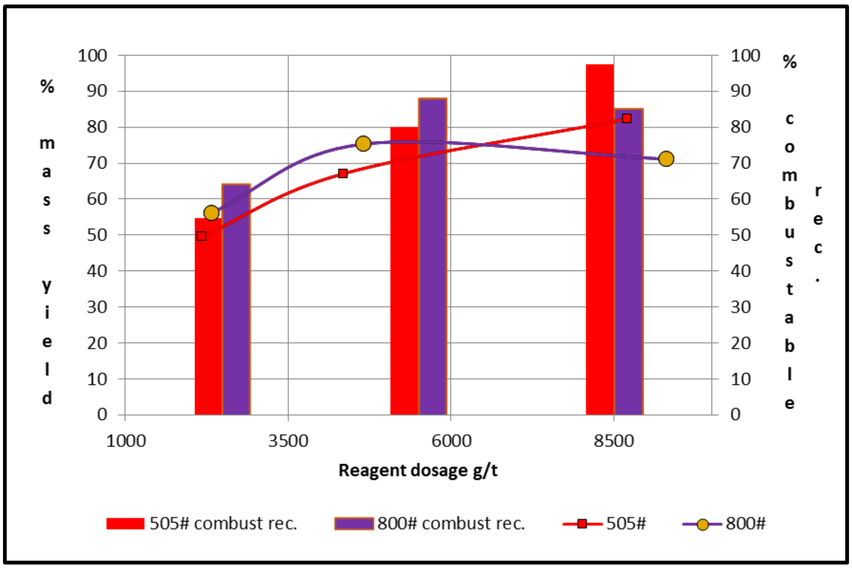

Figure 3: Spiral discards sample flotation reagent dosage versus percentage combustible recovery and mass Yield.

The results from the separation efficiency of the combustible matter and the ash by the flotation process is indicated in Figure 4.

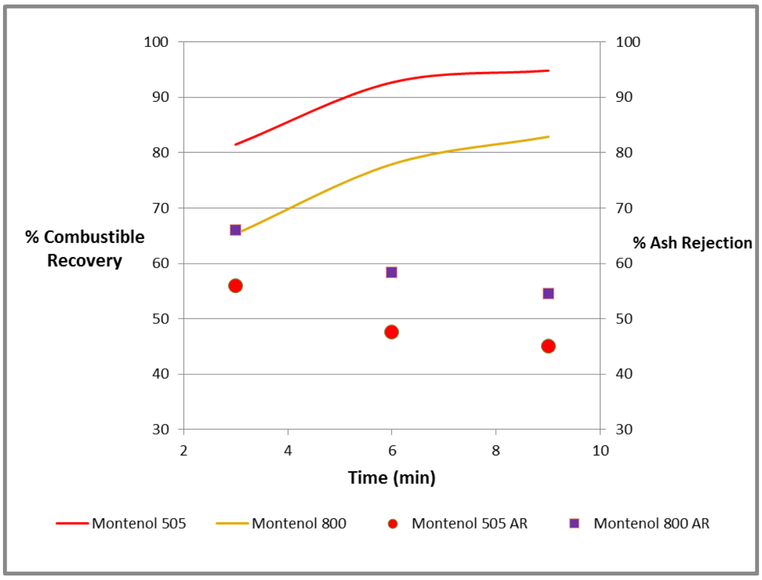

Figure 4: Flotation Kinetics on un-milled spiral discard at definite commercial reagent dosages of 8.3- 9.3 Kg/t.

Both Montenol 505 and 800 have displayed good flotation efficiency with 95% and 83% combustible recovery respectively. The percentage ash rejection for the two reagent decreases with increased recovery of combustible matter, where they dropped to 45% and 55% for Montenol 505 and 800 respectively. The efficiency of the flotation process can be measured by the gap between the combustible materials and the ash rejection at a certain time Between the two reagents, Montenol 505 had the highest flotation efficiency as the amount of ash rejection is lower than that of Montenol 800. The flotation efficiency of Montenol 505 is displayed by the separation efficiency of the combustible materials with the ash during the flotation process, this is displayed on Figure 5 at different milling times.

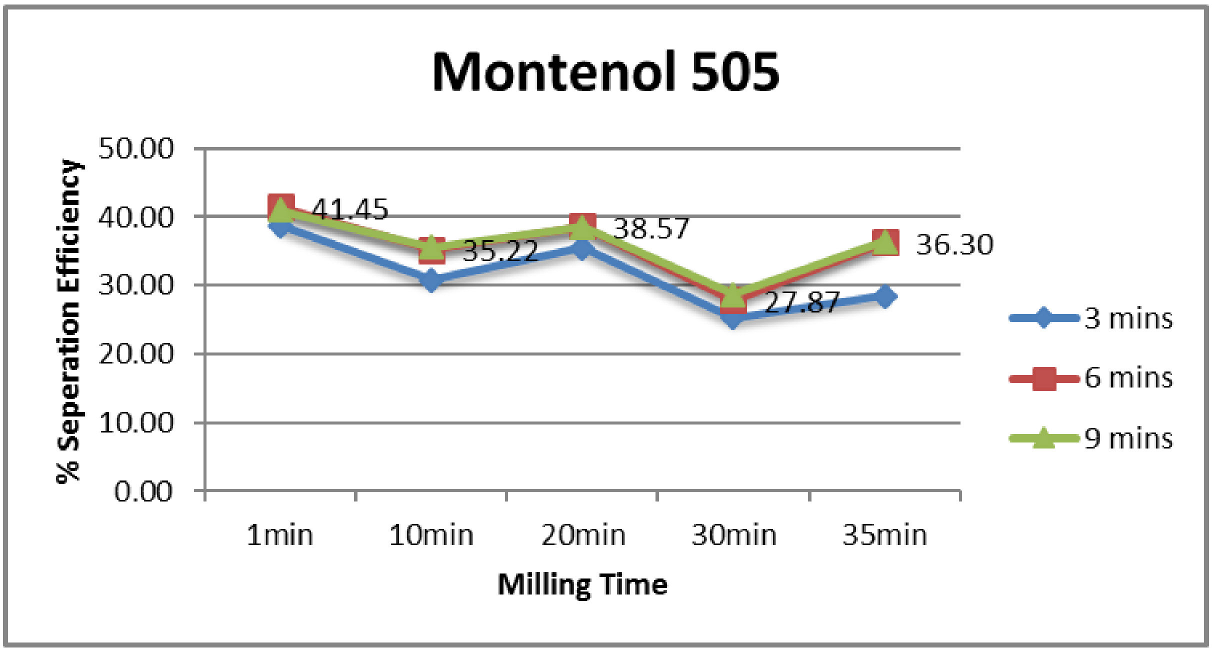

Figure 5: Effect of size reduction on flotation performance using Montenol 505.

Even though the grindability effect of coal had a negative impact on the flotation of the sample considered, Montenol 505 had an average of 35.88 separation efficiency over the different milling times. Milling the sample for just 1 minute proved to have the highest separation efficiency on all floatation times. Even though flotations have yielded good results, one should bear in mind that the users would reject one reason coal is because of the finer particle sizes. It is for this reason that the float product be agglomerated to produce good quality pellets that can withstand the impact during the handling and transportation processes.

3.4 Agglomeration

Three binders were chosen and experimented on, which are Sucrose, Floticor 8000 and Diesel all at two different concentrations. Agglomeration of the float product was proved to be possible with all the binders used as indicated on Figure 6.

Figure 6: Pellets produced from the laboratory experiments using the different binders.

Various particle sizes were obtained when agglomeration was done using the chosen binders. The pellets were dried and compressed to assess their strength variation per binder used. The challenge of choosing a perfect binder therefor lies in the improvements of the product quality which in this work was considered to be the strength and CV upgrade, results are displayed on Table 2.

Table 2: Overall results comparing the strength of pellets obtained from agglomeration using different binders and their respective effects on the CV upgrades.

Binder	**Compressive strength of green pellets (KN/m^2)**	**Compressive strength of dry pellets (KN/m^2)**	**CV Flotation feed (MJ/Kg)**	**CV Flotation Product (MJ/Kg)**	**CV Pellets (MJ/Kg)**
Sucrose 10%	38	> 650	17.031	20.458	21.573
Sucrose 15%	41	>650	17.031	20.458	20.676
Floticor 8000 10%	40	>650	17.031	20.458	20.458
Floticor 8000 15%	42	>650	17.031	20.458	20.540
Diesel 10%	35	560	17.031	20.458	24.316
Diesel 15%	32	540	17.031	20.458	25.726

The Flotation process was able to upgrade the coal CV from 17-20MJ/kg and this was the feed for agglomeration. For Sucrose and Floticor 8000, the higher percent concentration yielded higher green pellets strength and this was the opposite for Diesel. Sucrose and Floticor 8000 both resulted in pellets that are higher than 650KN/m2 irrespective of the binder concentration. Diesel at a lower concentration of

10% yielded dried pellets of 560KN/m2, whilst that of 15% yielded died pellets of 540 KN/m2. Diesel proved to be the most favourable binder as it upgraded the spiral discards to the highest CV of 24-25MJ/Kg.

4. SUMMARY

Spiral discards sample contained a reasonable volatile matter, and upgrading this sample would be beneficial to the coal industry. Grindability of the spiral discard sample considered is directly proportional with the grinding time. Montenol 505 had the better results because of the following;

- The higher combustible recovery with increase in time considered for the experiments,
- The lower ash rejection obtained from the experiments as a function of floatation time,
- The higher separation efficiency of the combustible and ash content in the sample.

In terms of agglomeration, the considered binders achieved similar particle size distribution for the pellets obtained. Sucrose and Floticor 8000 concentration had a direct correlation with the strength of green pellets. The later binders produced dry pellets over 650KN/m2 in strength. Flotation process by Montenol 505 upgraded the CV of coal by 20.12%, while a further 51.05% upgrade obtained by agglomerating coal fines using Diesel at 15% concentration.

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