

THE EFFECT OF MAGNETITE GRADE ON SEPARATION EFFICIENCY

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ABSTRACT

Magnetite is the medium of choice for dense medium separation in the coal industry and for most applications, fine grade medium is used. The circulating medium densities employed in the coal industry range from 1.3 to 2.0 t/m³ and both static and dynamic separators are used as separating vessels. South African magnetite is commercially available in three different size gradings i.e. medium, fine and ultrafine. In order to understand the impact of medium selection better, a series of tests have been conducted using pilot plant static (610 mm WEMCO design drum) and dynamic separators (165 mm dense medium cyclone). The effect of different combinations of medium grade and density on separation efficiency for different separators has been evaluated and the results correlated against the rheology of the medium.

INTRODUCTION

Four grades of magnetite with different size distributions were used. To assess the impact of the magnetite on separation efficiency, a pilot scale dense medium test rig was used together with coal as a feed. The floats and sinks fractions from each test were analysed using densimetric (float/sink) analysis. The feed was reconstituted using the floats/sinks results and the yield and partition curves calculated.

MAGNETITE CHARACTERISATION

The main parameters used to characterise magnetite are particle density and the particle size distribution.

Particle Density

Particle density is measured using a helium pycnometer. An accurately measured mass of sample is placed in a sample container of fixed and known volume. Helium gas is introduced into the container until the volume is filled. The volume of the container minus the volume of helium added is the volume of magnetite in the container and then density can be calculated by dividing the mass by volume.

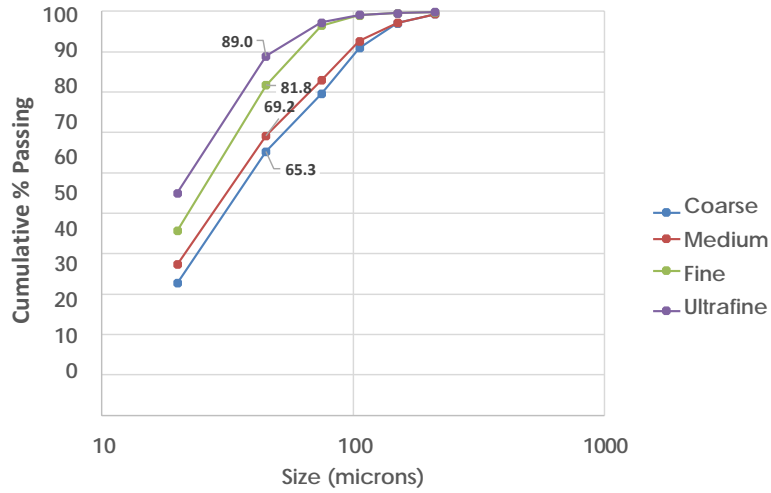
The results for the four grades of medium are tabled below:

| Magnetite Grade | Particle Density (t/m ³) |
|-----------------|--------------------------------------|
| Coarse | 4.81 |
| Medium | 4.84 |
| Fine | 4.93 |
| Ultrafine | 4.86 |

Particle Size Distribution

The samples are dried and deagglomerated before sizing is done. The particle size distribution is measured using a sieve shaker down to 45 microns. The minus 20 micron

fraction is measured using an Air Jet Sieve. The size distributions for the four grades are shown below:



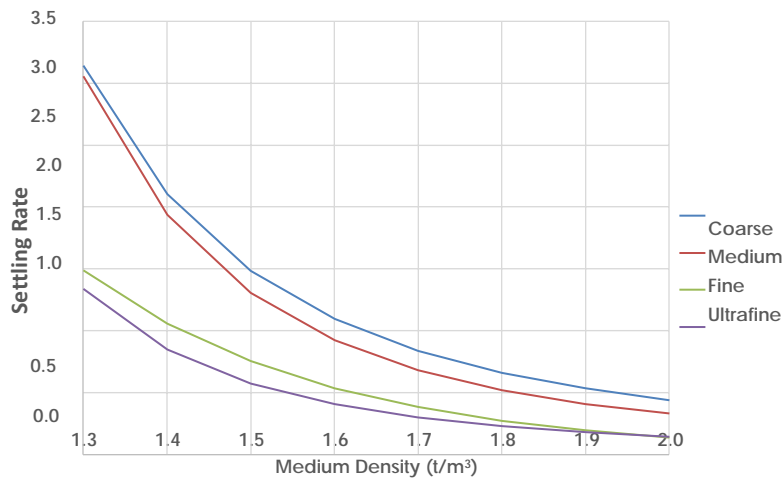
The percentage minus 45 microns for each grade is shown on the graph.

MAGNETITE RHEOLOGY

For a given medium density, magnetite rheology is defined by both settling rate and viscosity.

Settling Rate

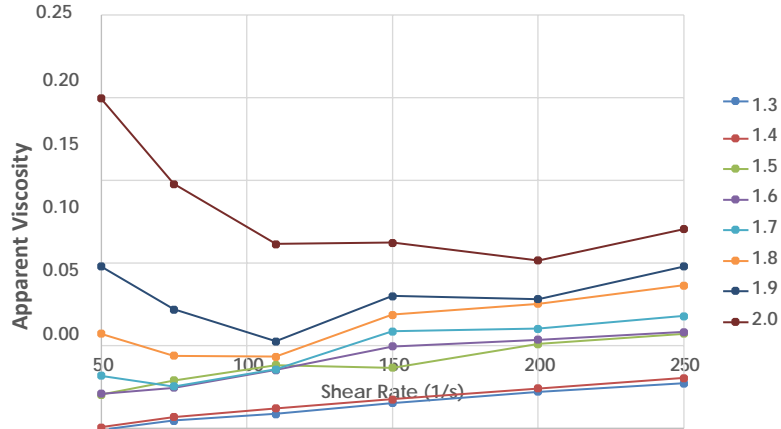
A medium of the required density is made up by adding magnetite and water in the required ratio. For settling rate determination, a 250 ml measuring cylinder is normally used. Due to its density and gravity, magnetite will settle out of the medium suspension over time. During this settling process, an interface between the water and the settling magnetite can be observed. By tracking this interface (often referred to as the mudline) as a function of time, the settling rate can be measured. Settling rate is a function of both medium density and magnetite particle size distribution. The settling rates for the four grades are shown below:



The coarse grade settles out the fastest, while the ultrafine grade settles out the slowest.

Viscosity

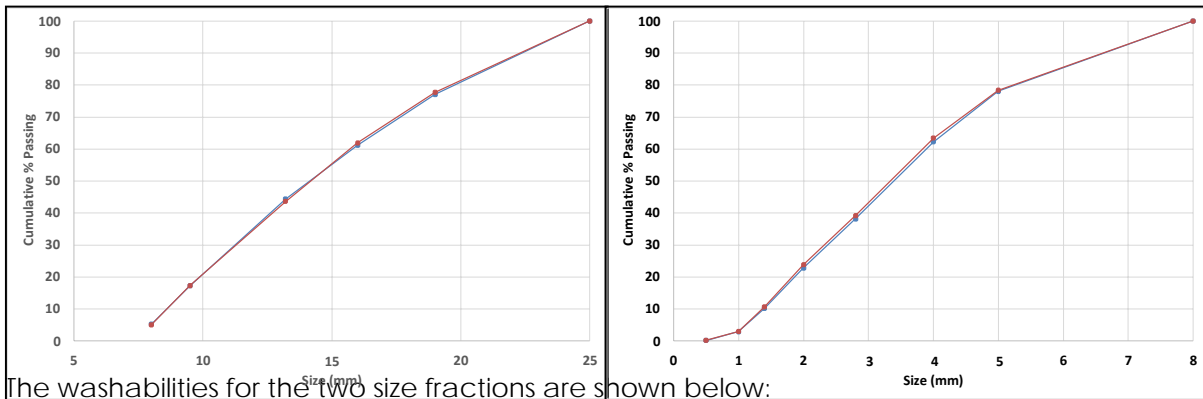
Measuring the viscosity of a settling slurry is very difficult and no standards exist. A vane type rheometer has proven to give repeatable results. The vane is used to both suspend the medium and then measure the shear stress for a given shear rate. To obtain a meaningful result, all tests are done in triplicate and each test is repeated three times. The result for ultrafine magnetite over the medium density range from 1.3 to 2.0 t/m³ is shown below:



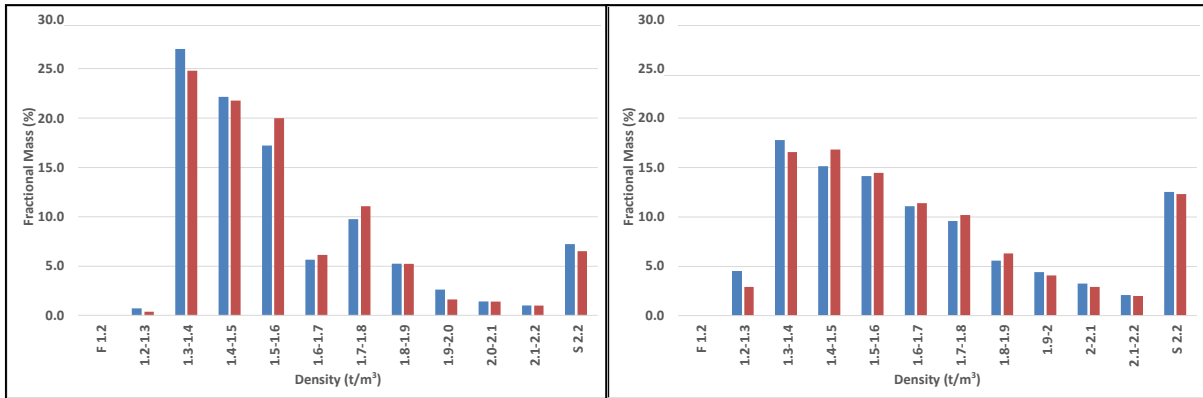
There are two important features to note i.e. the medium is non-newtonian and as the medium density increases, so does the apparent viscosity.

COAL CHARACTERISATION

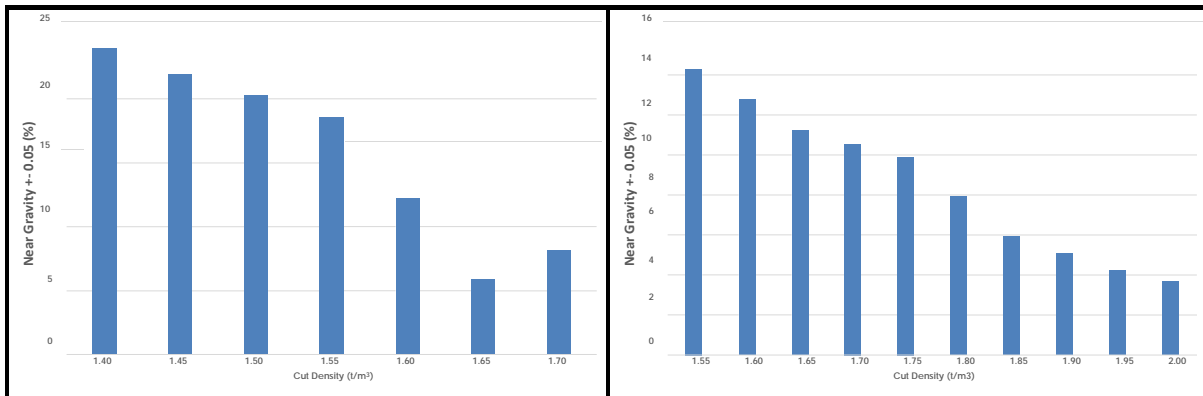
Two sources of coal were obtained for the test work i.e. a coarse coal (25x8 mm) and a fine coal (8x0.5 mm). The size distributions are shown below:



The washabilities for the two size fractions are shown below:



To assess the difficulty of separation, the near gravity (± 0.05 density units) was calculated. The results are shown below:



The coarse coal has more near gravity material than the fine coal, but in both cases, the separation is not too difficult. As the cut density increases, the amount of near gravity decreases.

PILOT PLANT TEST WORK

The test work was conducted using a 610 mm drum separator for the coarse coal and a 165 mm cyclone for the fine coal. In both cases the medium is recycled, but the floats and sinks are recovered separately off the end of a drain screen.

EXPERIMENTAL DESIGN

A full factorial experimental design was performed with the following factors, levels and responses:

Factors: medium grade and medium density

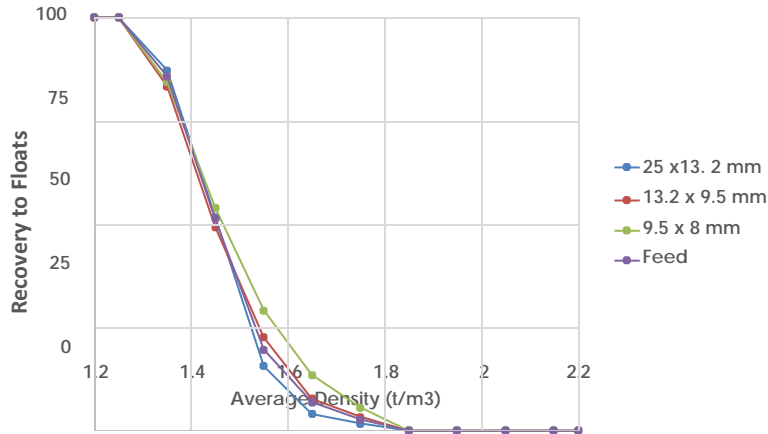
Levels: medium grade (coarse, medium, fine and ultrafine), medium density (1.4 and 1.6 t/m³).

Responses: Yield to floats, Floats and Sinks washability per size fraction, Partition curves calculated from the yield and washabilities.

COARSE COAL RESULTS

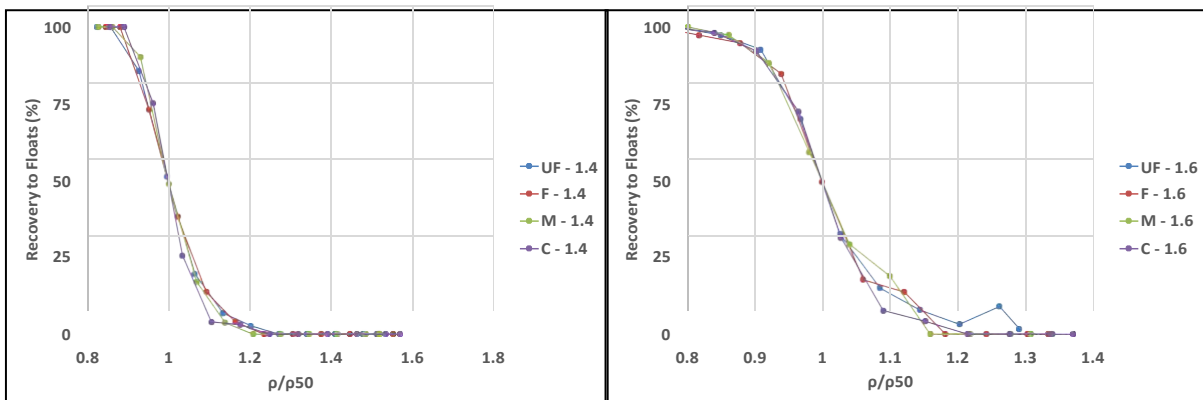
The results are presented using partition curves which describe how the coal is recovered to floats as a function of particle density.

The effect of particle size on separation efficiency is demonstrated using the result from a test run at a 1.4 medium density using ultrafine magnetite.



The coarser size fractions have more efficient (sharper) separations compared to the finer size distributions.

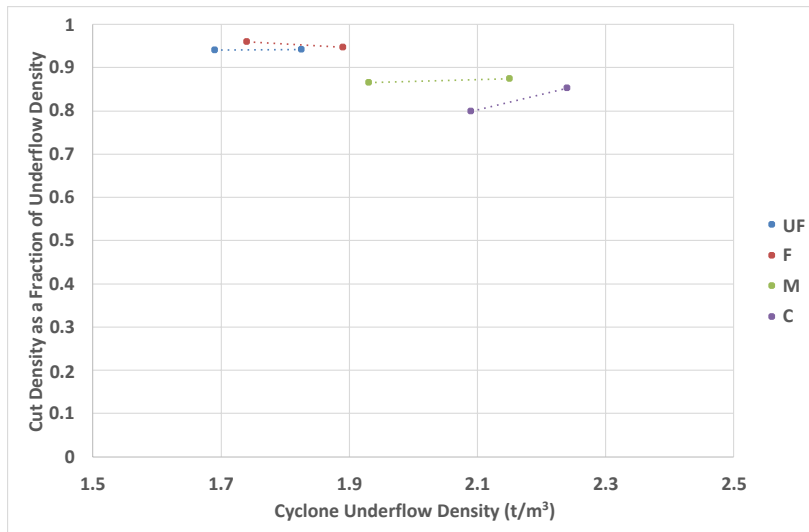
To assess the impact of medium grade on separation efficiency, the overall results for 1.4 and 1.6 medium densities are compared. As the different grades of medium resulted in different cut densities for the same medium density, the results have been normalised so that the 50% recovers to floats corresponds to a normalised cut density of 1. This is achieved by dividing the average densities by the cut density for each test. The results for the 1.4 and 1.6 medium densities are shown below:



The separation at the 1.4 medium density is sharper than that achieved at the 1.6 medium density. This can be attributed to the increase in viscosity at the higher density. In both cases the coarse grade resulted in a slightly better overall performance. This can be attributed to the lower viscosity of the coarse grade compared to the finer grades. The settling rate was not so high as to cause instability in the drum.

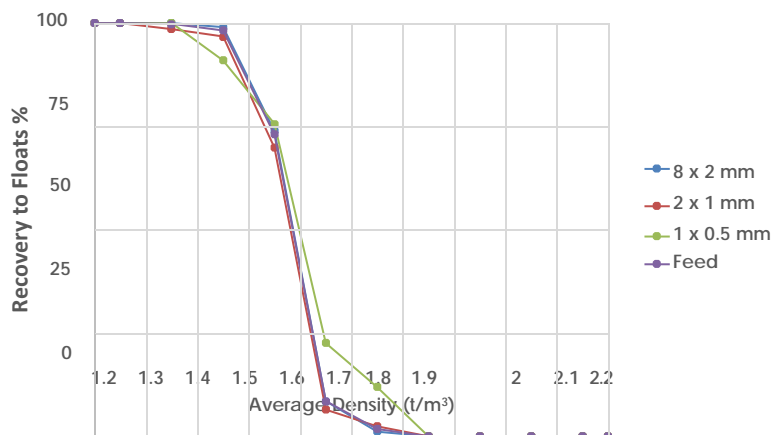
FINE COAL RESULTS

There is a strong relationship between the cyclone underflow medium density and the cut density as shown below:



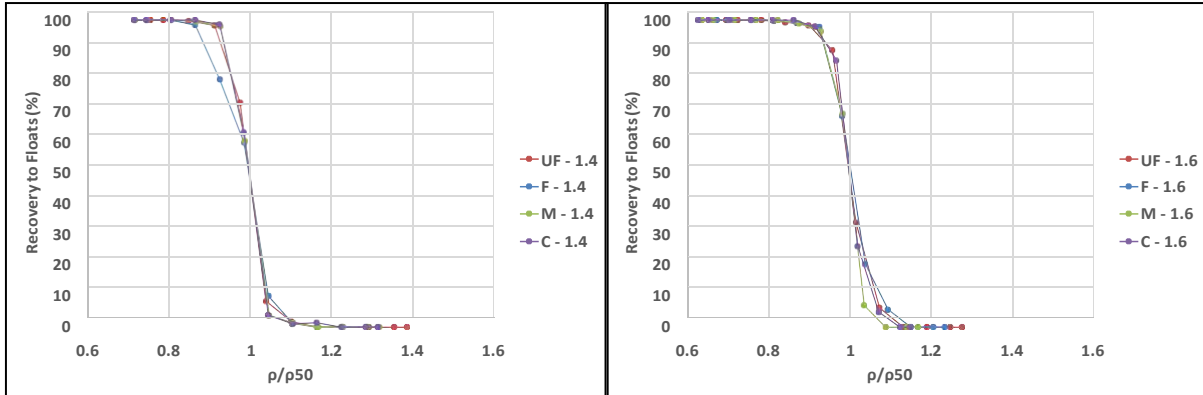
The cut density lies between 0.8 and 0.95 of the underflow density. The lower value is associated with the coarse grade and the higher value with the finer grades. In other words, the finer the grade of magnetite, the closer the cut density comes to the underflow medium density.

The effect of particle size on separation efficiency is demonstrated using the result from a test run at a 1.4 medium density using ultrafine magnetite.



The 1x0.5 mm fraction separates with a poorer efficiency compared to the coarser size fractions.

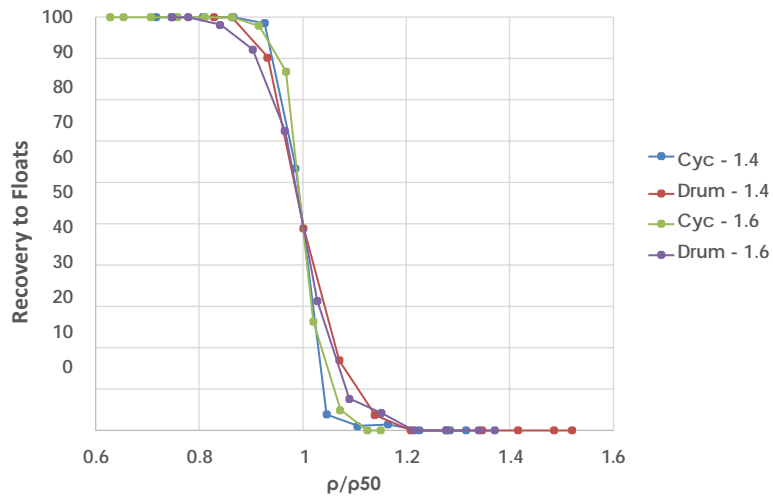
As with the coarse coal tests, the normalised results are used to compare the effect of the different grades of medium.



The separation efficiency at the 1.6 medium density is better (sharper) than that achieved at the 1.4 medium density for all the grades of medium. This is due to the higher viscosity at the higher density which offsets the centrifugal force associated with cyclone separators. Medium density appears to have a greater effect than medium grade on separation efficiency.

EFFECT OF SEPARATOR TYPE ON EFFICIENCY

Normalised partition curves were used to compare the relative efficiency of the drum compared to the cyclone.



At both 1.4 and 1.6 medium densities, the cyclone provided a more efficient separation than the drum. This can be attributed to the centrifugal forces which act on the coal particles.

CONCLUSIONS

Coarse Coal

The cut density is the same as the feed medium density. For the drum separator, the coarse grade of medium gave the best overall results. This grade of medium had the lowest viscosity, but was also the most unstable (had the highest settling rate). This would imply that medium viscosity is more important than medium stability (settling rate) for the 610 mm drum used for the test work.

Even with relatively large coal particles, the smallest size fraction (9.5x8 mm) showed a deterioration in efficiency.

Fine Coal

The cut density lies between the cyclone feed and underflow density and is strongly correlated with the underflow density.

For the cyclone separator, the medium grade of magnetite provided the best overall results. Its viscosity and settling rate fall in the middle for the different grades tested. There was not however a major difference in the effect of the different medium grades for the 165 mm cyclone.

The relative efficiency of the finest size fraction (1x0.5 mm) was poorer compared to the coarser size fractions in spite of the high centrifugal forces arising from using a 165 mm diameter cyclone.

OVERALL

Medium grade does play a role in the separation efficiency and is more pronounced for the drum compared to the cyclone.

Overall the cyclone is more efficient than the drum.