Magnetic field

Daniel Norrgran, Eriez, North America, describes the operation of wet drum magnetic separators for heavy media application, operation and performance.

Figure 1. Wet drum magnetic separators for heavy media application. Self-levelling counter-rotation tank style.

Within the last few years there has been a renewed interest in wet drum magnetic separators used for heavy media applications. This is largely due to the increasing costs of magnetite. A wet drum magnetic separator that was once viewed as a necessary ongoing expense may now be viewed as an avenue to significant cost savings to the operation. This has recently led to increased activity, with coal wash plants upgrading the magnetite recovery circuit.

Over the years, wet drum magnetic separators have evolved under the assessment of plant operation and performance. Major improvements have occurred in the magnetic element, materials of construction and ease of operation and maintenance. This article describes the design and engineering of wet drum magnetic separators, the parameters of operation and the metallurgical performance.

Wet drum magnetic separators for heavy media applications have had a very long history. The initial intent of the wet drum magnetic separator was simply to recover the magnetite circulating in the heavy media circuit. Over the years the wet drum magnetic separator was basically viewed as a necessary utility. This perception continued to the point that the separators essentially became a commodity purchased primarily on price. In most cases the magnetic separators were not highly efficient, providing only adequate magnetite recovery coupled with relatively high maintenance.

Over the years, the perception of wet drum magnetic separators has transformed. Innovations in both magnetic circuit design and materials of construction have been applied to wet drum magnetic separators. This results in maximum magnetite recovery while operating with a minimum amount of wear and maintenance. Refinements in the magnetic circuit, tank design and drive system have resulted in further improvements in metallurgical performance and operation. Wet drums are now viewed as an integral part of the process and when properly applied will result in efficient operation. The operation can result in significant savings in magnetite consumption. It is not uncommon for preparation plants to report an annual saving in excess of US$ 100,000 in magnetite consumption with efficient wet drum magnetic separator operation. Wet drum magnetic separators commonly used in heavy media coal circuits are illustrated in Figure 1.

Wet drum magnetic separator components

The wet drum magnetic separator consists of a rotating magnetic drum situated in a tank that receives the feed slurry. The magnetic drum consists of a stationary, shaft-mounted permanent magnetic circuit completely enclosed by a rotating drum. The magnetic drum is mounted in a tank. Slurry is fed to the tank and subsequently flows through the magnetic field generated by the drum. The ferromagnetics are attracted to the drum shell by the magnetic circuit and are rotated out of the slurry stream. The ferromagnetics discharge from the drum shell when rotated out of the magnetic field.

Magnetic element

The magnetic element is the most important feature of a wet drum separator. In the design of a magnetic separator, the magnetic field intensity and the magnetic field gradient are two first order variables that affect separation response. Although there are several variables influencing magnetic separation, the magnetic field strength is indisputably the foremost variable for high levels of magnetite recovery.

The typical magnetic element consists of a series of agitating magnet poles that span an arc of 120 to 140˚ as shown in Figure 2. The magnetic poles are arranged alternating from north to south to provide agitation of the magnetite as it is transported on the drum shell.

There have been recent technological advances in the design and modelling of magnetic circuits. Precise magnetic circuit modelling and optimisation is now carried out using multi-dimensional finite element analysis. The input is a scale design of the magnetic circuit; the output is a contour plot of the generated magnetic field intensity and the magnetic field gradient. This methodology provides an accurate depiction of the magnetic field configuration. A model of a magnetic element is shown in Figure 3.

There are several different designs of magnetic elements available. They range from the basic concept of either an axial or radial design, to the size, shape, and number of magnetic poles. However it is designed, the magnetic element needs a high magnetic field strength at the drum surface as well as a substantially high magnetic field gradient for effective magnetite collection. A graph depicting the magnetic field strength of a current design wet drum magnetic separator for heavy media applications is presented in Figure 4.

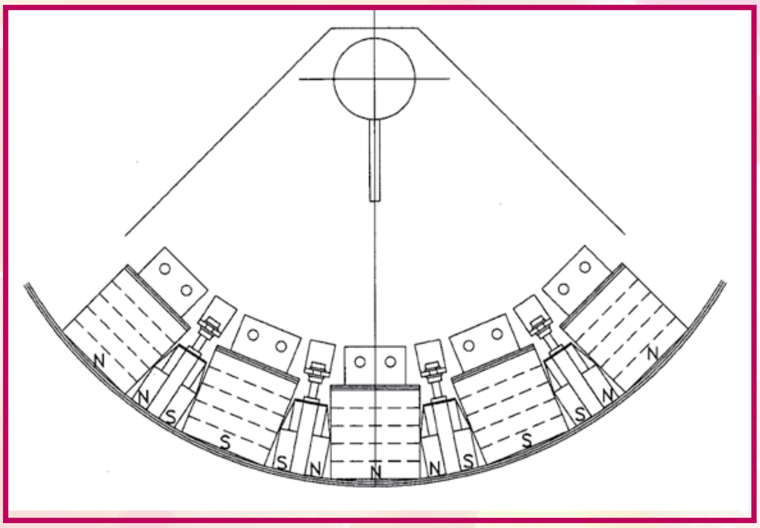

Figure 2. Typical wet drum magnetic element. The magnetic element consists of a series of magnetic poles that span an approximate 140˚ arc. The magnetic poles alternate from north to south to provide an agitating effect to the magnetite as it is being transported along the drum.

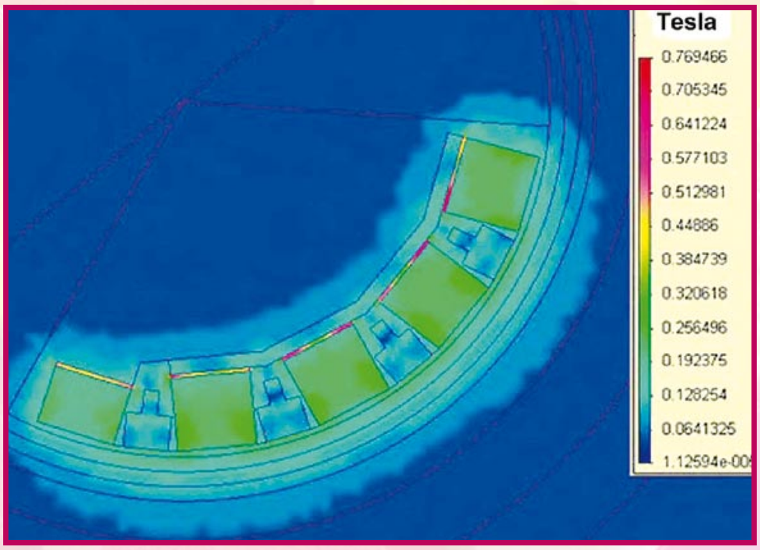

Figure 3. Finite element analysis and modelling of a wet drum magnetic element. Contour plot details magnetic field intensity and magnetic field gradient.

Tank

Heavy media operations commonly employ 0.9 and 1.2 m (36 and 48 in.) diameter wet drum magnetic separators ranging up to 3.0 m (10 ft) in drum width. Historically two different basic tank styles have been employed in heavy media applications, concurrent and counter-rotation. These tank styles are illustrated in Figure 5.

With the concurrent tank style, the drum rotates in the same direction as the slurry flow. The slurry enters the feedbox and is channelled underneath the submerged drum. The slurry flows through the magnetic field generated by the drum. The magnetite is attracted to the magnetic element, collected on the drum surface and rotated out of the slurry flow. A shortcoming of this basic design is that any magnetite that is not immediately collected will exit the tank with the non-magnetics.

The counter-rotation wet drum tank style is preferred for heavy media applications. The drum rotates against the slurry flow in the counter-rotation tank style.

The slurry enters the feed-box and flows directly into the magnetic field generated by the drum. The magnetite is attracted by the magnetic field, collected on the drum surface and rotated out of the slurry flow. Any magnetite that is not immediately collected will pass through to a magnetic scavenging zone. The short path that the magnetic material must be conveyed between the feed entry point and the magnetics discharge lip, combined with the magnetic scavenging zone, results in high magnetite recoveries.

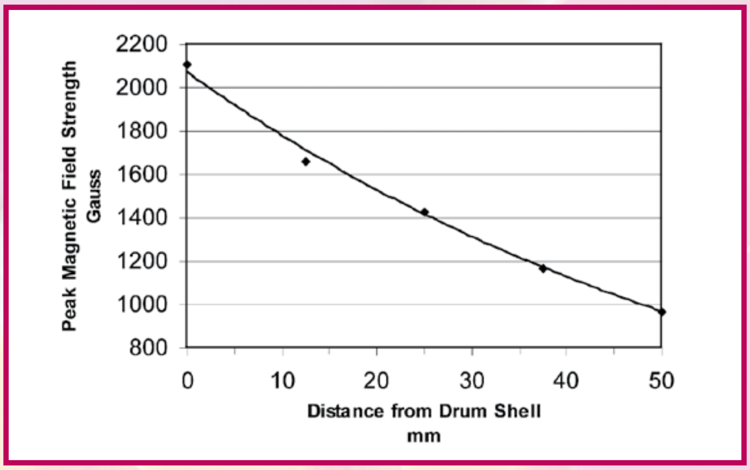

Figure 4. Magnetic field configuration of a wet drum magnetic separator. 0.9 m diameter wet drum magnetic separator 950 gauss interpole magnetic element. The graph is a function of magnetic field strength at distance and is characteristic of a current design 0.9 m (36 in.) diameter wet drum.

Extensive sampling of wet drum magnetic separators in heavy media applications has indicated that the industry standard for magnetite losses is 0.25 g of magnetite/litre of non-magnetic product. Figure 6 demonstrates the typical performance of a wet drum magnetic separator operating in a coal preparation plant employing a heavy media circuit. The wet drum magnetic separator was 0.9 m diameter with a counter-rotation style tank. This separator was isolated in the dilute heavy media circuit. The feed contained 111 g magnetite/litre, or approximately 10% soilds as magnetite. The feed rate was incrementally increased with samples of the non-magnetic product taken at each level. The magnetite level was measured in each non-magnetic product sample.

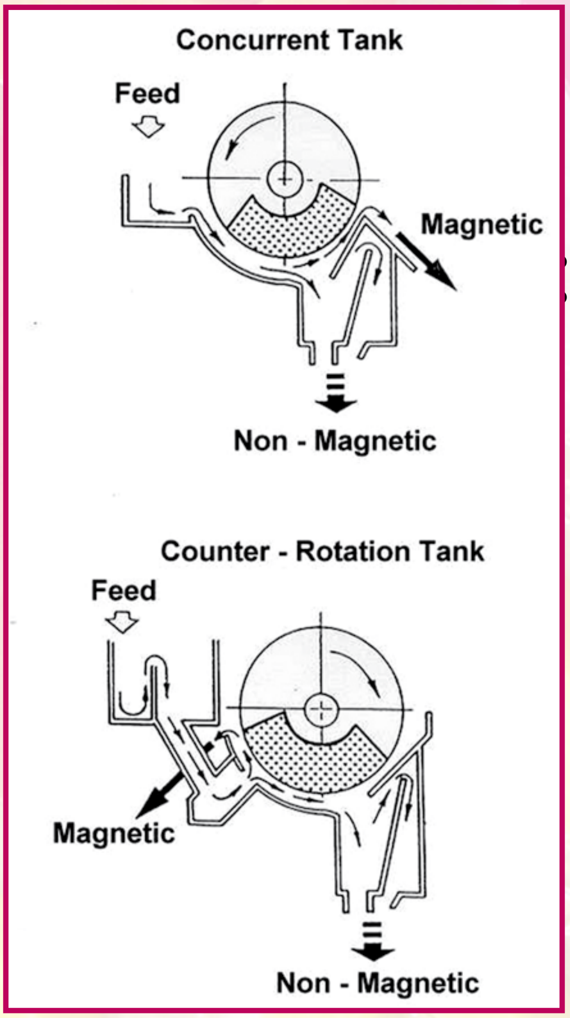

Figure 5. Schematic illustration of two wet drum magnetic separator tank styles in widespread use. The counter-rotation tank style provides a 'built-in' scavenging stage resulting in higher magnetite recovery.

Essentially all wet drum tanks used in heavy media applications have levelling spigots and a full width overflow that must be maintained during operation. A deviation in the overflow may result in inefficiencies in the performance and the loss of magnetite. A modification of the counter-rotation wet drum tank represents a recent development in technology for heavy media wet drum magnetic separators. The self-levelling tank has no discharge spigots to adjust or monitor. The tank maintains a constant slurry level at any flow rate.

Wet drum sizing and separator parameters

The purpose of the wet drum magnetic separator in a coal preparation operation is to recover magnetite in the heavy media circuit. When properly applied, the magnetic loss to the wet drum non-magnetic effluent will be reduced to less than 0.25 g of magnetite/litre of effluent. This generally equates to a magnetite recovery in the 99.8 to 99.9% range. In order to meet this performance, a number of conditions must be satisfied, including magnetic field strength, tank design and various feed slurry parameters.

Feed factors affecting drum performance

In a wet drum separator, the magnetic force acting on a ferromagnetic particle is predominately opposed by hydrodynamic drag force. This feature, when properly applied, provides the vehicle of separation washing away the non-magnetic particles while the ferromagnetic particles are collected in the magnetic field. The hydrodynamic drag force is also responsible for any losses of ferromagnetics. The factors affecting the recovery of the magnetite in the system are as follows:

- Slurry volume.
- Magnetic loading.
- Percent solids in feed slurry.
- Magnetic concentration.
- Ratio of non-magnetics to magnetics in feed solids.

The sizing of the wet drum magnetic separator is based on the slurry volume and the magnetic loading. The percent solids, magnetic concentration and the ratio of the non-magnetics to the magnetics all affect the magnetite recovery, as well as the specific gravity of the recovered product. These factors all have such empirical limits. Exceeding these empirical limits will negatively affect the system's performance. The empirical limits for each factor are examined in more detail as follows.

Slurry volume

Slurry volume is a primary factor in sizing wet drums. Magnetite recovery is directly related to the unit capacity or flow rate through the separator. As the flow rate increases, the slurry velocity and consequently the fluid drag force increases, which tends to detach or wash away magnetite particles from the opposing magnetic field. Excessive feed slurry volume will result in increased magnetite losses and a lowering of concentrate gravities.

Table 1. Wet drum magnetic separator sizing parameters for heavy media application. Counter-rotation style tank. Heavy media sized (Grade E) magnetite. Feed slurry at less than 15% solids as magnetite

Drum diameter	Hydraulic sizing parameter	Magnetic loading sizing parameter
0.9 m (36 in.)	90 m^3/hour/m drum 120 GPM/ft drum	16 tph/m drum 5.5 tph/ft drum
1.2 m (48 in.)	120 m^3/hour/m drum 160 GPM/ft drum	24 tph/m drum 8 tph/ft drum

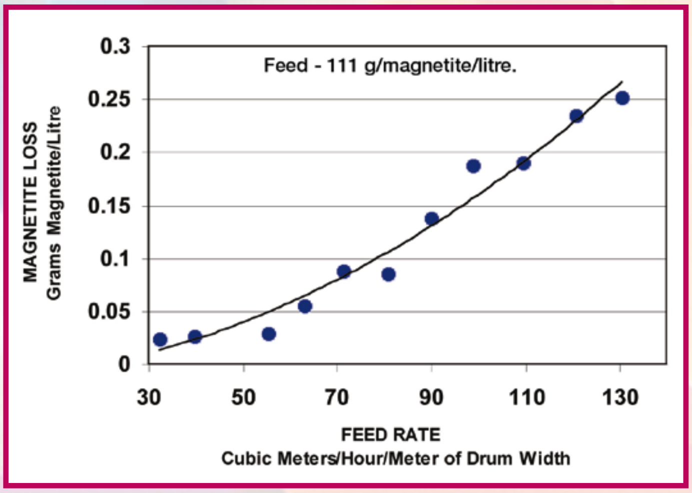

Figure 6. Wet drum magnetic separator performance. Magnetite loss as a function of feed rate.

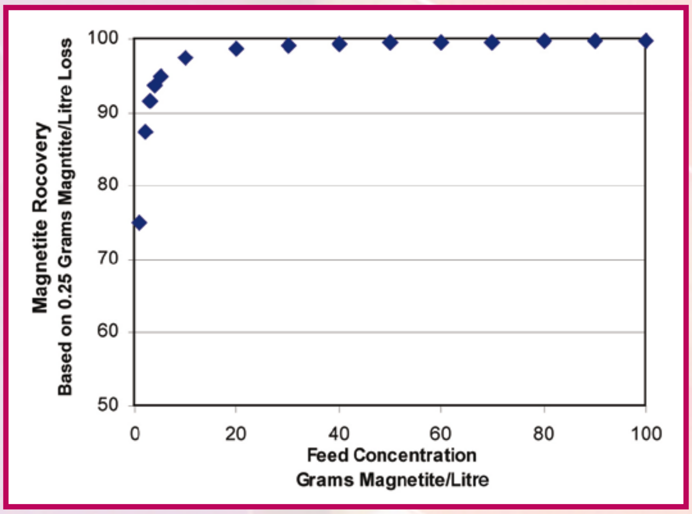

Figure 7. Magnetic separator efficiencies throughout a range of magnetite content in the feed. Magnetite recovery is based on 0.25 g of magnetite/l

Magnetic loading

Magnetic loading or the amount of magnetite in the feed slurry is the other primary factor in sizing wet drum magnetic separators. Any given wet drum magnetic separator has the characteristic of removing a limited amount of magnetite based on the diameter of the drum, peripheral speed and the magnetic field strength. This is referred to as the 'magnetic loading'. Magnetic loading is measured as t of magnetite/hour/m of drum width.

In heavy media applications, magnetic loading is based on a value that will give the minimum loss to the non-magnetic product. Much higher loadings are possible, but will result in progressively exceeding the magnetic tailings concentration goal of 0.25 g of magnetite/litre of effluent. This will result in a deterioration of the magnetite recovery. Furthermore, cleaning performance will be degraded as more non-magnetics will be physically entrapped with the magnetite product. At high levels of magnetics in the feed slurry, a reduction in the feed rate or unit capacity of the separator will be necessary to achieve acceptable magnetite recoveries.

The slurry sizing parameters as well as the magnetic loading parameters for the 0.9 m and 1.2 m diameter wet drum magnetic separators are provided in Table 1.

Percent solids in feed slurry

The percent solids in the feed slurry will directly affect the selectivity of the separation. As the percent solids increases, the magnetite losses will increase due to the increased level of competition in the magnetic field. The specific gravity of the magnetic concentrate will also decrease due to increased physical entrapment of non-magnetics.

Slurry - percent solids as magnetics

Magnetite recovery is affected by the amount of magnetics in the feed slurry or the percent solids as magnetics. It is difficult at best to estimate magnetite recovery without analysing the magnetite content of the feed slurry. As stated before, wet drum magnetic separators will typically lose less than 0.25 g of magnetite/litre of effluent when properly applied. Under these conditions, if the feed slurry contained only 10 g of magnetite/litre, the recovery would be 97.5%. If however, the feed contained 200 g of magnetite/litre, the recovery would be 99.9%. Therefore, it can be seen that wet drum efficiency is dependent upon the amount of magnetics in the feed slurry. Figure 7 details separator efficiencies based on 0.25 g of magnetite/litre loss throughout a range of magnetite content in the feed.

Magnetic to non-magnetic ratio

The ratio of magnetics to non-magnetics influences both the magnetic recovery and the magnetic concentrate purity. When the non-magnetic fraction of the feed solids is more than 40% by weight it interferes with the magnetic material in the separating zone. The result is a loss of magnetics and a dilution of the magnetite concentrate.

Wet drum magnetic separator sizing

The sizing of wet drum magnetic separators must take into account both the hydraulic flow rate as well as the magnetite content. The magnetic loading is directly proportional to the magnetite content of the slurry or the percent solids as magnetite.

Sizing charts have been developed for the 0.9 m and 1.2 m diameter wet drum magnetic separators and are provided in Figure 8. These graphs provide the feed rate limitations at any given percent solids as magnetite.

Consider the sizing graph of the 0.9 m diameter wet drum magnetic separator. The separator must be sized within the hydraulic capacity and magnetite content boundaries. The boundaries represented by the outline designate the slurry capacity containing a total of 16 t of magnetite/hour/m of drum width.

Magnetite recoveries relating to a loss of less than 0.25 g magnetite/l

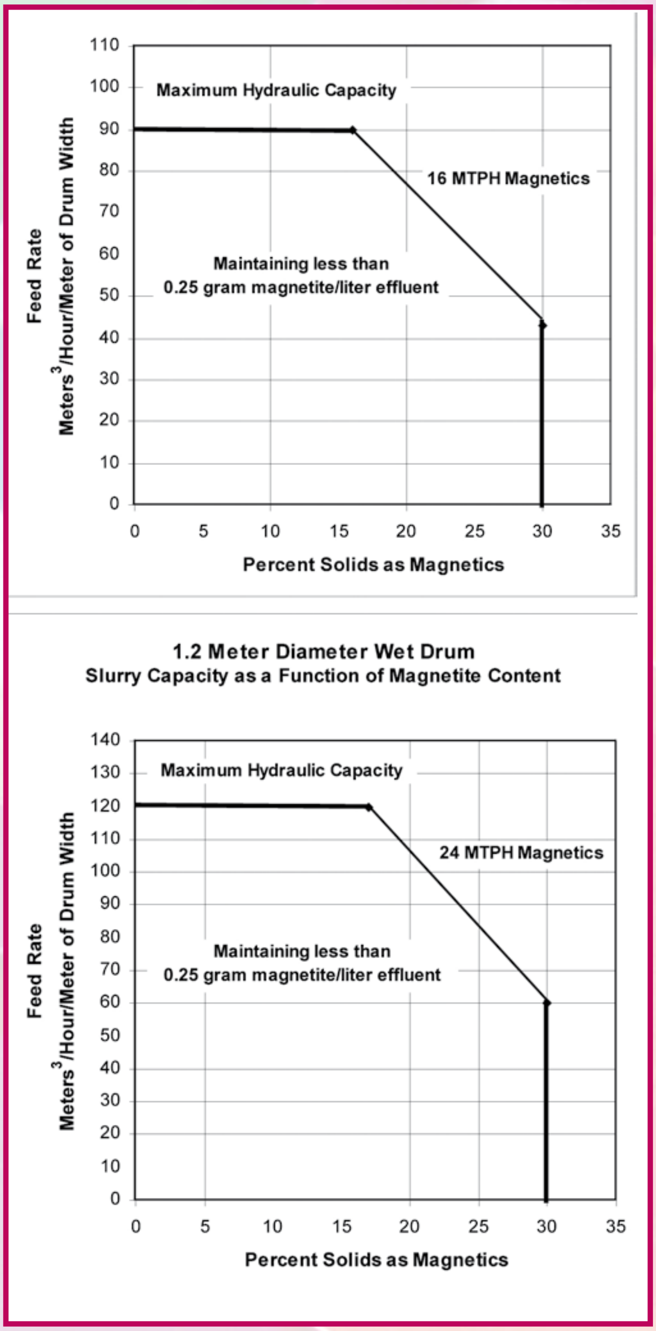

Figure 8. Sizing and performance characteristics of wet drum magnetic separators.

will be maintained when the slurry capacity is less than 90 m^3/hour/m of drum width and the solids in the feed slurry is less than 16% magnetite. When the magnetite in the feed slurry increases from the 16% solids, the slurry capacity must be proportionately decreased to maintain the high magnetite recovery.

Conclusion

There are several manufacturers of wet drum magnetic separators. Consequently there is an array of magnetic elements and tank styles to choose from. Even though the particular features of wet drum magnetic separators may vary, the basics remain the same. The magnetite has to be attracted and collected from the flowing slurry.

The operating and sizing parameters are based on extensive testing and sampling of wet drum magnetic separators operating in the Appalachian region of the US. ■