It is well known throughout the coal industry that loss of magnetite adds significantly to the cost of producing clean coal. It is also known that the best way of attracting and recovering magnetite is via magnetic wet drum separators, now a staple part of coal production. However, often these drums do not operate effectively and their performance deteriorates, resulting in huge losses of magnetite and, therefore, money.

Before committing to the significant expense of pulling wet drum separators out of service, it is crucial to ensure that the drums are faulty. This can be achieved by regular testing, as it provides a comparison, allowing deterioration to become obvious before significant magnetite losses occur.

The magnetic system in a drum separator has a reduced ability to attract magnetite if its magnetic profile has changed. There are many reasons why this occurs. The most common is when magnetite leaks into the drum, short circuiting the magnets and altering the profile of the magnetic field.

The magnets can also become damaged or broken. On some occasions, extreme temperatures can cause magnets to be weakened.

### The basic principles of magnetic separation

Magnetic separation is used for the concentration of minerals and for the removal of suspended magnetisable particles in a fluid. As a method it depends on the behaviour of different minerals under the influence of a magnetic force.

Minerals can be classified into three groups: whether they are attracted to, repelled by, or unaffected by a magnet.

- **Paramagnetic minerals** are attracted in the direction in which the field intensity increases. In almost all cases, this results in attraction aligned with magnetic flux urging particles towards a magnetic surface. They can be concentrated in high intensity magnetic separation.
- **Ferromagnetic minerals** are generally included in this classification as they are attracted in the same way.
Ferromagnetic materials can be strongly magnetised by a low external field. Diamagnetic minerals are repelled in the direction of decreasing field intensity. The forces involved are small. Diamagnetic substances are not concentrated magnetically except by bench-scale equipment.

The capacity of a magnet to lift a mineral is not only dependant on the field intensity but also on the field gradient, i.e. the rate at which the field intensity increases towards the magnet surface.

Paramagnetic minerals have higher permeability than the surrounding fluid (water or air) and therefore concentrate the lines of force of an external magnetic field. Thus, the higher the magnetic susceptibility, the higher the density in the particle and the greater its attraction up the field gradient towards increasing magnetic strength.

Diamagnetism results from induction in a substance of magnetic moment opposite in direction to the external field.

All magnetic separators are designed to provide a magnetic field gradient, either in the gap between the poles of a magnetic circuit or in the air space near the magnetised surface, such as that of a permanent magnet.

One effect of the field gradient is to induce stronger magnetism. The particle then experiences a translational force that urges it in the direction of increasing field intensity.

Simple methods of producing a field gradient are a v-shaped pole above a flat pole. Alternate magnetic and non-magnetic laminations also produce field gradients. By placing ferromagnetic elements in a magnetic field to serve as secondary poles, a number of separate regions can be provided in which field gradients are effective for separation.

The shape and orientation of the ferromagnetic elements determine their degree of magnetisation and the field intensity gradient adjacent to their surfaces.

For continuous machines the speed at which material passes through is also important. Flocculation of particles is also often avoided by passing material through consecutive magnetic fields, usually arranged with successive reversal of the polarity. This causes the particle to turn through 180°, with the reversal releasing entrained particles. The main disadvantage of this is flux leakage from pole to pole, which reduces the effective field intensity.

The translational magnetic forces on magnetisable particles is of the form:

$$F = \frac{V k \text{grad}(B^2)}{2 \mu_0}$$

Where $k = $ volume susceptibility and $V = $ particle volume. This formula holds for weakly magnetic particles but is also valid (with some restrictions, such as demagnetisation factor and saturation) for more or less strongly magnetic particles.

To obtain high forces, the factor grade ($B^2$) or $|B|$ has to be optimised in the separation volume. This volume ranges from outside the drum radius to the bottom of the trough.

What is needed is high flux density and high gradient. But if the aim is for a high gradient at the drum surface, the flux density will decrease rapidly in the radial direction. To obtain high forces at the outer region of the working volume, the gradient has to be adjusted carefully depending on the specific application (grain size, throughput rate, gap width, etc).

Once attracted to the drum surface, particles must remain there when being transported to the magnetic discharge. Field gradients parallel to this path (i.e., variations of the magnetic field that are identical to transverse forces) should thus be minimised. Such transverse forces hold particles in the regions of relatively higher fields and give rise to clogging and losses of magnetic particles.

On the other hand, many pole changes on the path along the drum surface are advantageous. Strongly magnetic particles rotate with changing polarity, and non-magnetic particles, which might be captured by the clogging of some magnetic particles, can be freed. This leads to cleaner products and better selectivity.

The optimum situation is therefore high flux density at the drum surface, high field gradient according to the requirements of the specific application and many pole changes, plus minimum variations of the absolute field value on the drum surface.

**Testing the magnetic field profile**

The only way to conduct a test that gives enough information for accurate comparisons is to use a system that represents the complete magnetic profile of the drum. A few measurements using a handheld magnetic probe or gauss meter will not suffice because the measurements cannot be repeated with any reliability and they do not gather enough information.

Magnetic measurements need to be taken at regular intervals around the complete magnetic portion of the drum. The readings must measure both horizontal and vertical magnetic vector components. Several thousand measurements need to be made so that the magnetic profile can be mapped accurately. International Magnetic Solutions (IMS) has developed a purpose-built instrument (patent pending) for carrying out such a procedure.

This diagnostic procedure measures the strength, direction and position of the alternating magnetic field pattern produced by the drum in three locations along the axis of the drum: at the drive end, centre and non-drive end. If a standard, even shape is seen, the magnets are in good working order. A distorted shape means that there is a problem and the system is not operating efficiently.

The complex reading given by this test will confirm the condition of the magnetic wet drum, enabling a confident decision on whether to simply adjust it or take it out of service for repairs.

**Magnetic field profile**

The magnetic field radiating from the drum is made using a series of magnets, arranged in alternating north/south patterns facing radially from the drum. This arrangement creates a magnetic field profile that may be described as having two major directional components. One component (the vertical) is in a radial direction from the drum, while the other component (the horizontal) follows around the
vertical fields radiate from the drum and horizontal fields are parallel to the circumference of the drum. They both alternate, varying in strength and north/south direction around the circumference of the drum (Figure 1). The strength and gradients in this magnetic profile control the efficiency of the magnetite recovery.

The graphical results show how these fields vary in strength and polarity. The graphs indicate the north pole in red and the south pole in blue. The test results show the vertical and horizontal field patterns together and separately at each test position.

These field patterns directly influence the recovery efficiency of the drum. Any alteration to the magnetic field pattern will result in lower recovery and higher magnetite losses.

Field gradient

The IMS system is so precise and accurate that any alteration to the magnetic system will show an obvious distortion to the pattern on the graphs (Figure 2). The ability of a magnet to attract a mineral is not only dependant on the field intensity but also on the field gradient (the rate at which the field intensity increases towards the magnet surface). Put more simply, the way the magnetic strength changes over distance has a direct effect on the magnetic attractive force experienced by particles.

In non-magnetic terms, it is similar to the knowledge that, for any given height, the slope on the side of the hill controls the acceleration experienced by a ball rolling down it.

If it were possible to see the magnetic strength profile around a magnetic drum, it would look like a wave pattern. The shape of the wave pattern controls the amount of attractive forces experienced by the magnetite particles in the water near the drum. A steep sharp wave pattern will result in higher forces on the particles than a slightly undulating pattern.

All magnetic separators are designed to provide a magnetic field with a high magnetic field gradient. The magnetite particle then experiences a translational force that urges it in the direction of increasing field intensity.

Magnetite leaks

Internal magnetite leakage is a problem that will reduce efficiency, as the magnetite is able to enter the inside of the drum through the damaged outer skin or through the seal between the end plate and outer skin. A large build-up of magnetite lying on the magnet assembly short circuits, absorbs and changes the gradient of the magnetic flux, resulting in less available magnetic force on the outside of the skin.

Conclusion

The IMS testing equipment gives an internal picture of the state of wet drums and advance notice of ensuing problems, preventing excessive damage and an unexpected shutdown due to equipment failure. Testing of all of the drums belonging to a mine can be carried out in one day during a scheduled shutdown of a line. Testing is carried out with the assistance of a technician from the mine itself, under IMS supervision. This eliminates the need for costly induction expenses. IMS has found several pieces of faulty magnetic equipment in both New South Wales and Queensland – and believes this could be just the tip of the iceberg.
FAST, ACCURATE REPAIR AND MAINTENANCE OF MAGNETIC WET DRUM SEPARATORS

Our team of professionally qualified magnetic engineers and specialised tradesmen have helped numerous plants restore their wet drums to maximum efficiency.

- Simple service or major repairs in minimum time
- Latest model replacement parts guarantee optimum performance
- High quality maintenance ensures long term, trouble-free operation of your machinery

Moved, damaged or magnetite covered magnets often go unnoticed but can seriously increase your operating costs. Getting IMS to test and maintain your machinery will ensure you know exactly how your magnetic wet drums are operating and if their efficiency needs to be improved.

ACT FAST TO RESTORE OPTIMUM PERFORMANCE AND AVOID EXPENSIVE REPAIRS IN THE FUTURE.

Certified Transport and Lifting Frames

Our certified transport and lifting frames make it easy and safe to transport and lift Magnetic Drum Separators.

IMS transport and lifting carriages have been specifically designed by engineers and certified to be safe for Storing, Transporting and Lifting the magnetic drums by crane to the top of the CHPP.

The Frames are fitted with colour coded lifting lugs for lifting by crane and lashing lugs for securing to transport vehicles. Lifting and Lashing diagrams are attached to the frames as well as a numbered certification plate indicating the Tare and the Working Load Limit (WLL).

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