

**Tramp Iron Removal with actively controlled electromagnets:
An opportunity for simultaneously achieving power savings, increased
effectiveness and reduction in capital cost**

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1 Executive Summary

The South African mining and energy sector utilizes a significant number of electrically powered tramp metal removal magnets, estimated at approximately 1500 units in 350 operations. The total energy consumption of these machines is of the order of 400 – 500 MWh per day, of which 80% could be saved through improvements in the control of these machines.

The required improvement in control can be realized through the combination of metal sensing equipment and a suitable controller with the electromagnet.

2 Quantifying the energy savings potential in modification of tramp Iron removal technology

2.1 Background

Tramp iron removal is essential in number of industries, predominantly the coal industry, power generation and hard rock mining. Tramp iron damages conveying, crushing and processing equipment, leading to unscheduled downtime, productivity loss and safety hazards. Electromagnets are employed to remove the iron from conveyor belts. In South Africa, approximately 350 mining, beneficiation and power generation operations are the most significant users of tramp iron removal equipment.

Current magnet technology in South Africa is that electromagnets are permanently energized. In most operations, tramp Iron only arises infrequently with a few extraction events per day or per hour. This means that the tramp iron removal equipment operates most of the time in a wasteful state whereby electricity is wasted as heat and dissipated into the environment without any beneficial use.

It is possible to reduce this wastage by 80% or more through simple measures, including the control of the magnetic equipment through metal detectors, and the implementation of an appropriate control philosophy.

This proposal broadly outlines the economic justification and proposed technical realization.

2.2 Power consumption by suspended electromagnets

In South Africa, energy consumption by suspended electromagnets in the Coal, Diamond and Precious Metal sectors is estimated to be of the order of 400 – 500 MWh per day, the total energy equivalent of 10 000 – 15 000 average South African households. This figure is not dramatically high compared to other power consumers in the mining industry, such as pumping or size reduction. An opportunity lies however in the fact that most of the energy used in tramp iron removal magnets is spent unnecessarily. It is not necessary to keep the magnets fully energized when tramp iron arises only infrequently, as it usually does. This is the common plant practice now and is equivalent to leaving the lights on at home when going on holiday. The energy saving potential and comparison to other current initiatives is significant. Assuming that power consumption of suspended magnets can be reduced by 85%, 200 000 – 300 000 households would, for example, require a full exchange of incandescent light bulbs (a current national energy saving initiative) to fluorescent or LED lighting in order to achieve the same energy saving.

3 Technical realization

3.1 Control and operating philosophy

Instead of operating the electromagnet continuously, it is controlled by a metal detector which senses metal approaching the electromagnet on the conveyor belt, and triggers the powering-up of the electromagnet, as described below.

- a) The metal detector is positioned at the underside of the conveyor, at a suitable distance – usually 10 – 20 m upstream from the magnet - and set such that it only triggers when metallic material passes close to the sensor, i.e. at the lowest point underneath the burden. This is the position from which it is hardest to extract tramp iron, and the highest magnet energy level is needed. Statistically, this is only required in a fraction of all occurrences. Tramp iron at higher levels is closer to the magnet and buried under less material and is therefore very much easier to extract.
- b) Assuming that the probability of tramp iron occurring at all on the conveyor at a particular time is $p_1 = 0.01$ (equivalent to approximately one tramp metal item per hour), and the probability of this item being in the 'deepest' third of the conveyor cross section is $p_2 = 0.3$, then the combined probability of having to operate the magnet at maximum intensity is $p = p_1 \times p_2 = 0.003$.
- c) The combination with a **DC current controller** and **integrated intelligent logic controller**, which actively controls the four parameters, namely: coil current (lower level), coil current (upper level), ramp – up time from lower to upper level, time at upper level. The benefits are as follows:
 - a. Coil current (lower level): Instead of switching the magnet on from zero current to max, the magnet will be continuously operated at a certain low energy setting. It can be shown that significant extraction performance can be achieved at a fraction of the power consumption. Maximum energy and power consumption is only justified for infrequent, difficult extraction cases. The magnitude of the low energy setting is one of the adjustments of the system and can be optimized from site to site. It can

be shown that the total power consumption of the system is lower for the case where the coil operates continuously at a low setting and only infrequently operates at the higher current level, than for the case when for every metal item the coil gets energized from zero to maximum intensity. Further, operating the magnet at a pre-set energy level reduces ramp-up time and helps minimizing mechanical contraction in the solenoid.

- b. Coil current (upper level): The upper level is the maximum current at which the coil can operate. This level is dependent on the required availability at this particular level and is closely related to the amount of heat generated due to coil resistance. Because the upper level current is only required at a fraction of time, rather than 100% of the time as is the case with uncontrolled systems, the current can be significantly higher and overall extraction performance is significantly better.
 - c. Control of current ramp-up time. This is only possible with the type of DC drive which Multotec has recently introduced and tested. Conventional designs use fixed-voltage transformer-rectifier systems. With a transformer-rectifier system, at every startup of the coil, a powerful DC current surge occurs ('current inrush'). This has several undesired consequences: All cabling, switch gear, power components, transformer has to be designed to cope with the size of these peak currents. Power draw peaks travel to the power grid. The large inrush current places the coil under mechanical stress when energized. Implications of this are relevant for equipment cost and equipment durability. With the ability to define a ramp-up time for the current to rise from low to high level, these negative effects are eliminated.
 - d. Time at high current level is controlled and set for a certain number of seconds after the metal has passed the metal detector.
- d) Additional/corollary advantages and benefits due to the proposed system:
- a. Better performance due to higher peak current allows for faster extraction and larger operating gap, reducing the likelihood of belt slitting or jamming of large tramp iron due to poor clearance between conveyor belt and magnet.
 - b. Multiple times better performance on 'borderline' cases: Conventional magnet systems are designed to deal with the 'average' size tramp Iron. Suppliers typically predict 90-95% average extraction efficiency. To bring the extraction efficiency up to 99%, it would be necessary to install equipment twice the size, and twice the cost. With actively controlled magnet energy it would be possible to achieve this performance with the same equipment size.
 - c. The system is insensitive to power grid voltage fluctuations and will always perform at the correct current
 - d. No transformer losses and all other benefits and savings due to no need for transformer
 - e. Reduced average power input leads to lower average coil temperature, which results in lower conductor resistance and reduced power consumption. This effect is significant: The temperature coefficient of conductor grade Aluminium is 3.8×10^{-3} /K. Between a coil temperature of 100 deg C and 30 deg C, the conductor resistance increases by close to 30%.

3.2 Quantification of benefits

Consider the scenario of a suspended electromagnet installed over a medium size conveyor belt, 1800 mm width, 35 degrees troughing angle. Throughput is 2000 tph of coal, and it is assumed that steel bars 10 x 10 x 100 mm are vertically randomly distributed in the layer of coal carried by the conveyor.

An obvious relationship exists between the current through the coil and the strength of the magnetic field, and the ability of the magnet to extract iron buried under a layer of nonmagnetic material. Increasing the current through the coil allows one to extract iron from deeper levels.

An undesired side effect of increased coil current is the increased generation of heat, which raises the resistance of the conductor, and reduces the coil current for a given DC supply voltage due to

$$I = U/R. \tag{1}$$

It also increases the power consumption due to

$$P = UI = RI^2. \tag{2}$$

Taking into account both effects, one can calculate the relationship between the minimum required power consumption of the magnetic circuit to extract the tramp iron from the particular depth of burden.

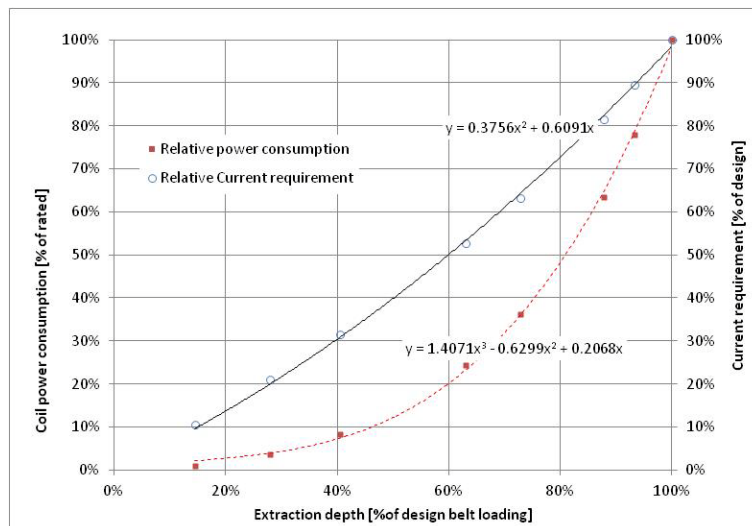


Figure 1: Relationship between desired extraction depth and coil power consumption

Figure 1 illustrates that a given electromagnet, which is designed to extract tramp iron from its ‘ design’ (100%) burden depth, can be operated at 50% of design power consumption if the burden depth is reduced by 20%. Accordingly, one could operate the magnet at 10% of rated power and still expect extraction of tramp iron in the upper 40% of the burden. To achieve extraction from the farthest point below the magnet requires the most power. The argument here is that these events constitute statistically a small fraction of the total population of extraction events.

Therefore the proposed approach is to operate the magnet continuously at a low intensity setpoint, and only increase the power if a metal detector senses material near the bottom of the conveyor.

By making certain assumptions about the quantity and distribution of tramp iron, it is possible to estimate the optimum settings of the control system for the lower level extraction depth.

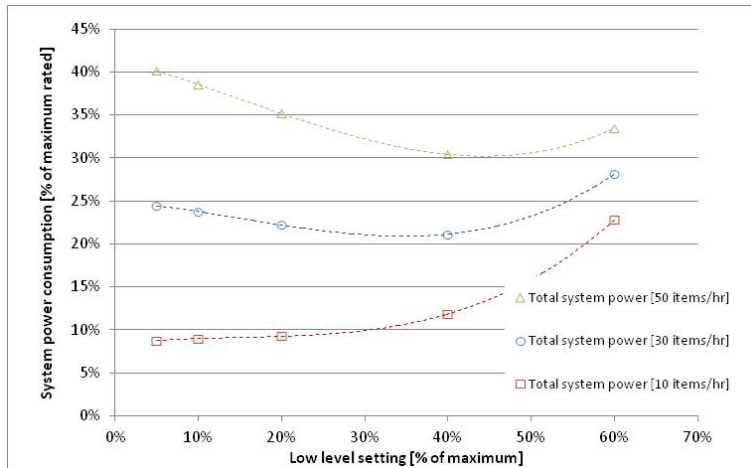


Figure 2: Total power consumption in relation to the low level setting of the magnet controller, for low, medium and high total values of extraction events

The conclusions drawn from this analysis, with regards to theoretically realizable power savings, are:

1. An actively controlled system can produce power savings of the order of 80 – 90% of design power.
2. For low tramp iron concentrations, the potential power saving is the highest.
3. An adjustable lower level of magnet intensity helps to optimize the power consumption and is beneficial in particular with high tramp iron concentrations.

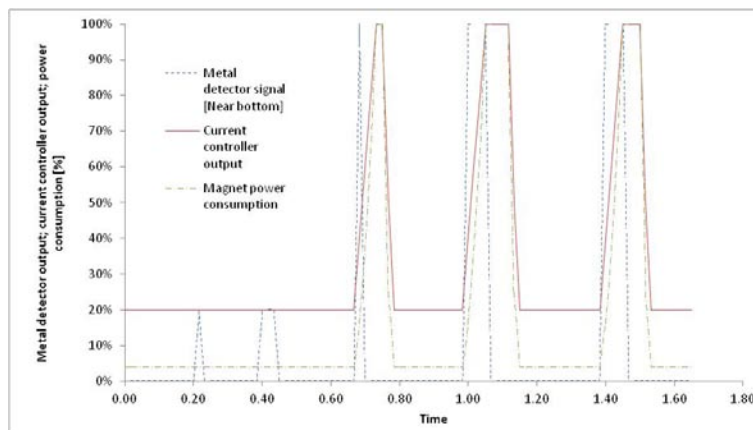


Figure 3: Indicative profile of trigger events and resulting power consumption

References

1. www.dmr.gov.za
2. South African Patent Application: 2012/06519: METHOD OF AND SYSTEM FOR EXTRACTING TRAMP METAL