The Production of Ferroalloys by the Toll Treatment of Slag Dumps

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Abstract

The worldwide production of ferroalloys has resulted in large deposits of alloy bearing slag. It is a relatively cheap source of ferroalloys, but ideally needs to be recovered in a size fraction and grade that is directly saleable, in order to maximise returns. Alloy producers, although aware of the potential existing in the dumps, have difficulties in exploiting these dumps for the following reasons.

(1) The current low market price in FeCr, FeMn and SiMn leaves producers with minimal capital for investment. It is more convenient to finance recovery operations out of running costs, than to finance large scale capital investments.

(2) The recovery process is a combination of ore dressing and gravimetric separation. The current employees of a pyrometallurgical facility would require specialised operations and maintenance training to operate such a plant. Another alternative is to specifically recruit people for such a plant. Neither of these is attractive given the finite life, in many instances, of the recovery plant.

(3) Some producers have relatively small or low grade deposits and this makes recovery operations seem uneconomical at first glance.

Toll treatment of a dump can alleviate a producer of these problems. The producer only has a commitment to pay a toll fee based on tonnage processed or metal produced, depending on which party will absorb the majority of risk.

Introduction

Slag dumps have been recognised as a potential source of ferroalloys for many years, with testwork having been performed at Mintek up to 20 years ago[1]

More recently Mintek carried out jigging tests on FeCr, FeMn, SiMn, FeV and other ferro-alloys, but the feed to the jig was limited by the restriction that it had to be fine enough to pass through the ragging and the screen on the bed of the jig. Another reason for only treating finer materials was that the standard diaphragm jigs did not have enough power to raise a bed of larger particles of high density metal and slag.

Titaco and Mintek jointly developed a process using high capacity pneumatic underbed air pulsed Apic jigs by which coarse clean saleable alloy can be recovered at a high throughput of feed. Where fine fractions exist, these can also be processed to produce clean alloy at high rates of recovery.

This process was developed to meet the immediate market needs of recovering saleable metal from large dumps and has been found to be the most favourable process for recovering ferro-aloys from slag dumps[2].

The need to treat low grade products and smaller sized deposits has resulted in the development of toll refining. The capital cost of such a plant can be amortized over a number of operations, thus reducing the toll fee that needs to be charged to economically operate the plant.

The Process

A process[3] can be tailored to the specific requirements of the material or client needs, but will generally incorporate the following basic elements.

Process Requirements

A successful metal-from-slag recovery plant should have the following features.

- The process should recover as much of the metallic content of the slag as possible (95% or better).
- The grade of product should be within that tolerated by purchasers (less than 2.5% slag in the metal).
- Metal should not be discarded, i.e. coarse (>3mm), fines (<100um) and ultra-fines (<100um) should all be recovered in size fractions directly saleable on the open market.
- Unliberated particles should be recycled in the process or recovered as a middlings fraction to be recycled in the smelter.
- Process media should be contained in order to minimise the release of soluble contaminants into the environment.
- The barren waste slag should be of a form that is not harmful to the environment and that can be used for landfill or aggregates.

Washability

The key operation in the recovery process is the gravimetric separation in the Apic Jig. It relies on being able to separate material due to a density difference. Although there is limited data on the washability of ferro-alloy slags, the data obtained on ores is indicative of the principle.

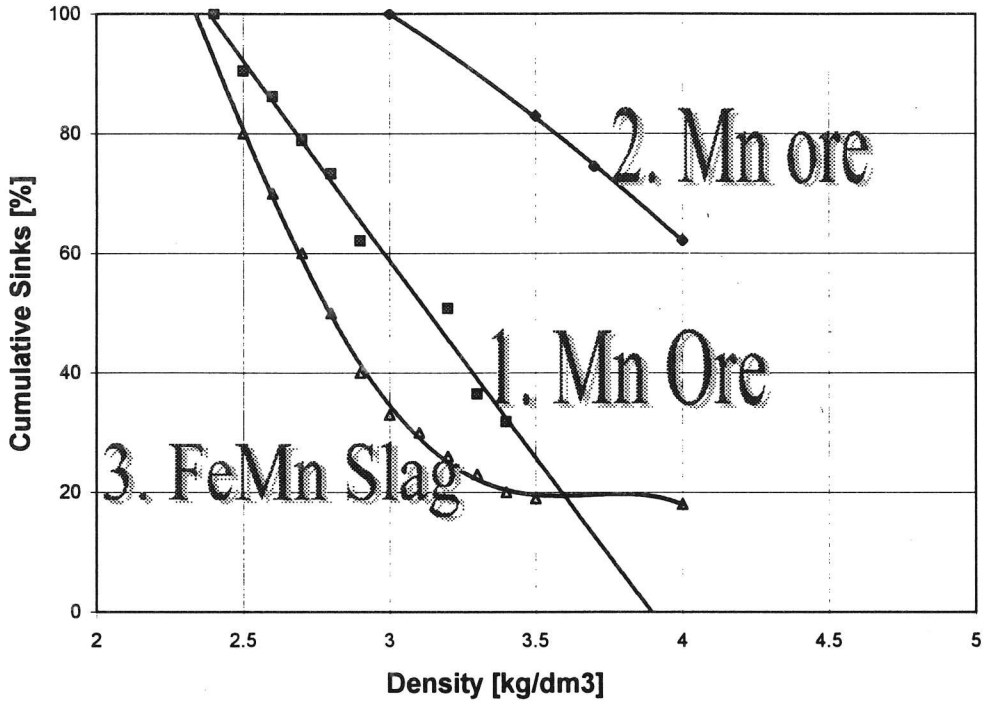

Fig. 1. Washability Curves for Manganese ores and slag dump material

In Figure 1, Washability Curve no 1 indicates a Manganese ore that is difficult to separate using a jig because of the larger percentage of near gravity material (NGM). Washability Curve no 2 shows less near density material, hence the ease with which the Jigging technique can achieve separation.

A curve for a ferro-alloy slag dump material (Washability Curve no 3 is indicative) would be much flatter, due to the larger difference in densities between valuables (metal) and discards (slag). The low percentage NGM will enable a jig to obtain a precise density separation.

Crushing and Screening

The tapping and casting practice of the respective alloy producers is significantly different, such that each dump has to be tested to determine the optimal liberation size for discrete course metallics. A crushing circuit, Figure 2 is a typical example, is then designed to maximise liberation of metal and minimise fines generation.

The screening stage is generally performed wet, so that dust generation can be minimised both for crushing and screening. The fine material can then be transported and recovered.

In the crushing, shear action is maximised so as to separate metal particles from slag and not generate too many fines. The crushing circuit is a closed circuit to maximise liberation. There is generally also a recycle of middlings fractions from the jigging stage.

Coarse Jigging

The design of a coarse Apic Jig for ferro-alloys generally has two compartments. The first produces a clean saleable concentrate and the second a lower grade middlings. This middlings grade contains unliberated alloy and can be recycled to the crushing stage or recycled to the furnaces. The typical circuit is shown in Figure 3.

An important factor in the success of the Apic jig is the controllability of air pulses and metal discharge through the gate. The jig operation adjusts automatically to changes in the feed composition.

Fines Jigging

The traditional method of recovering fines in a 'through-the-bed' jig can achieve high recoveries, but at the cost of lower grades, which affects the ultimate saleability of the product. It is also extremely difficult to automatically control the diaphragm jig to account for on-line feed grade variations.

The Titaco/Mintek joint venture has successfully modified the Apic Jig to treat finer material (-5mm) and to produce both through-the-bed and on-the-bed concentrates, both of sufficiently high grade to be directly saleable.

Water and Slimes Disposal

As water is used in the crushing and screening circuit as well as in the jigging circuit, the plant needs to be designed to contain the process water, both during normal running conditions and during an abnormal shutdown.

All discard waste material leaving the plant is dewatered, to ensure minimal loss of water from the circuit and to ensure soluble pollutants such as Cr6+ are retained in the water circuit for subsequent neutralisation.

Dump Amenability

The amenability of a slag dump for treatment is largely dependant the market value of the product, the size of the resource and grade of metal in the resource. The economics of these factors, together with the clients labour and capital restrictions, will determine the best approach.

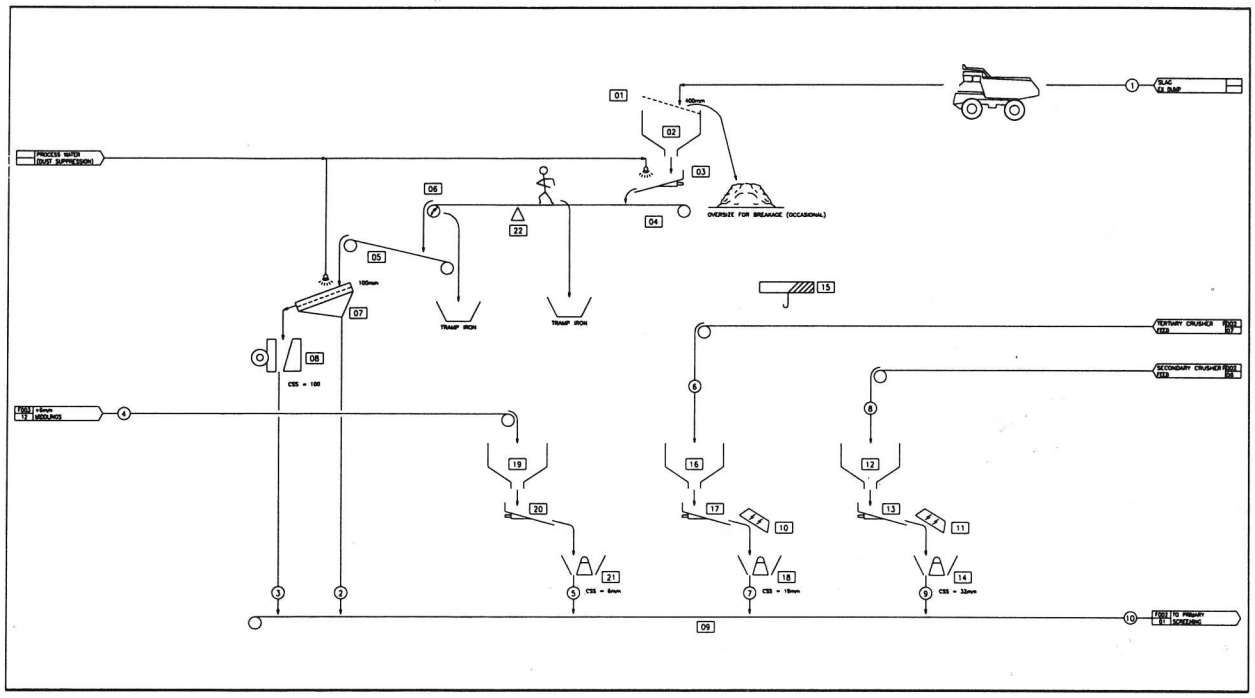

Fig. 2. Typical Flowsheet for ore recovery and crushing.

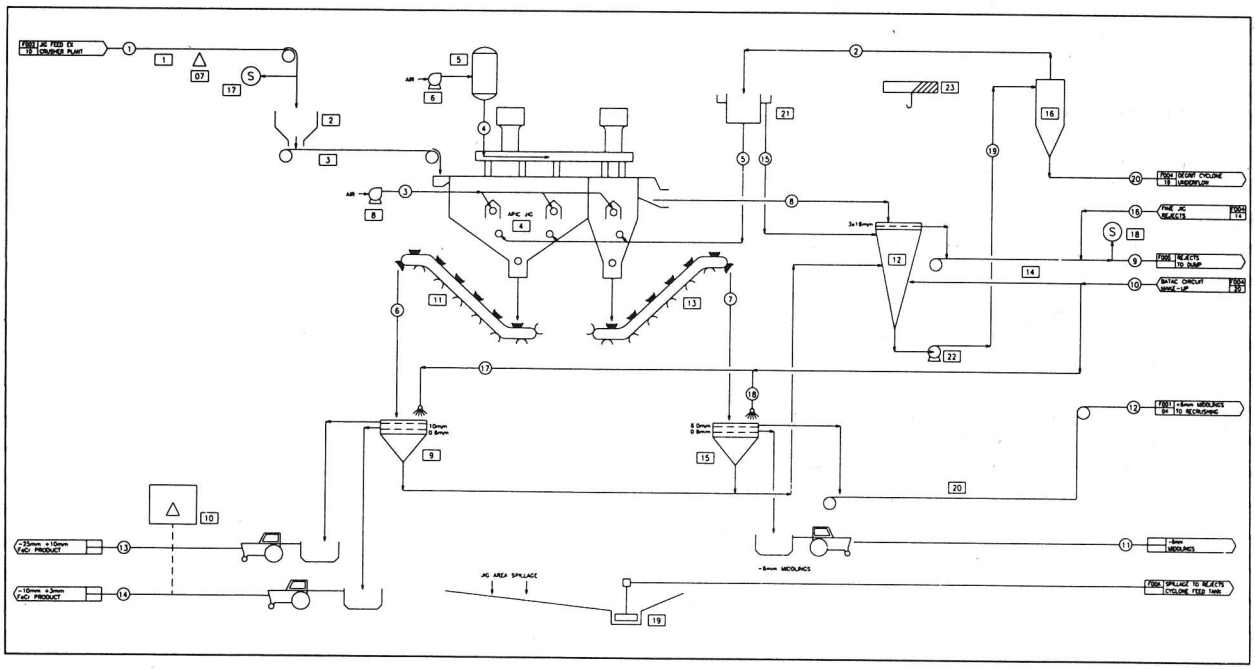

Fig. 3. Typical Flowsheet for Coarse Jigging

Large Scale Capital Plants
Titaco has successfully commissioned 6 large scale high tonnage client owned and operated ferro-alloy recovery plants in both South Africa and Zimbabwe.

Most of these dumps were large in size, in excess of 4 MT but relatively low grade, 3-5%. The only exception being a high grade deposit, 6-8% of relativly low size, 1 MT. In all cases the clients owned and operated the recovery plant.

It is worth noting that toll treatment is not excluded from the large scale dump or high grade deposits. It is in fact beneficial in some instances for large dumps to be processed on a toll basis, without the ferro-alloy producers having to employ staff to operate and maintain the plant.

Toll Treatment operations
The most basic assumption in the smaller scale operation is that the capital cost of the recovery operation will be amortised and recovered over more than one recovery operation. This enables a toll fee to be charged such that the economics of the operation enable both the client and toll operator to realise acceptable profit margins.

In Figure 4, the area to the right of graph 1, Large Scale, is typically the parameters within which large scale capital intensive plants are profitable. Graph no 2, Toll, indicates how the toll operation has extended the area of economically viable opportunities. Thus previously unprofitable opportunities can now be processed to the mutual benfit of both the toll operator and the client.

Technological Developments

In order to sustain this successful technological implementation, market needs and conditions have to be evaluated and solutions found for problems that arise. The following areas have been addressed and will lead to further technological developments.

Discharge Control
The original air pulsed Jig was designed for coal washing. In this application the concentrates float, while the gangue material is the sink. This means that accuarate gate control of the sinks is not critical, and neither is the contamination of the sinks with some floats a process consideration from a grade perspective.

In ferro-alloys the float and sink roles are reversed. A further complication is the fact that in coal about 50% of the jig feed in discharged through the gate, while in ferro-alloys the metal content is about 10% at maximum. For these reason the control of metal discharge (sinks) is critical. It will determine not only the efficiency of the process, but also the grade of product.

Mintek have patented the new gate mechanism, which was developed in conjunction with Titaco and implemented on the Apic Jigs. This new gate design reduces wear on the moving parts and allows a more homogeneous discharge of metal, which enables the bed level to be more consistent and thus a more efficient separation is acheived. It also allows for pulsation to occur before the discharge area, which limits the amount of dead area and thus the compaction of metal concentrate.

Pulsation Control
Another area where the Titaco/Mintek joint venture has made significant improvement is in the pulsation control.

Pulsation is adjusted continuously to ensure that pulse waveforms remain constant, regardless of bed propeties.

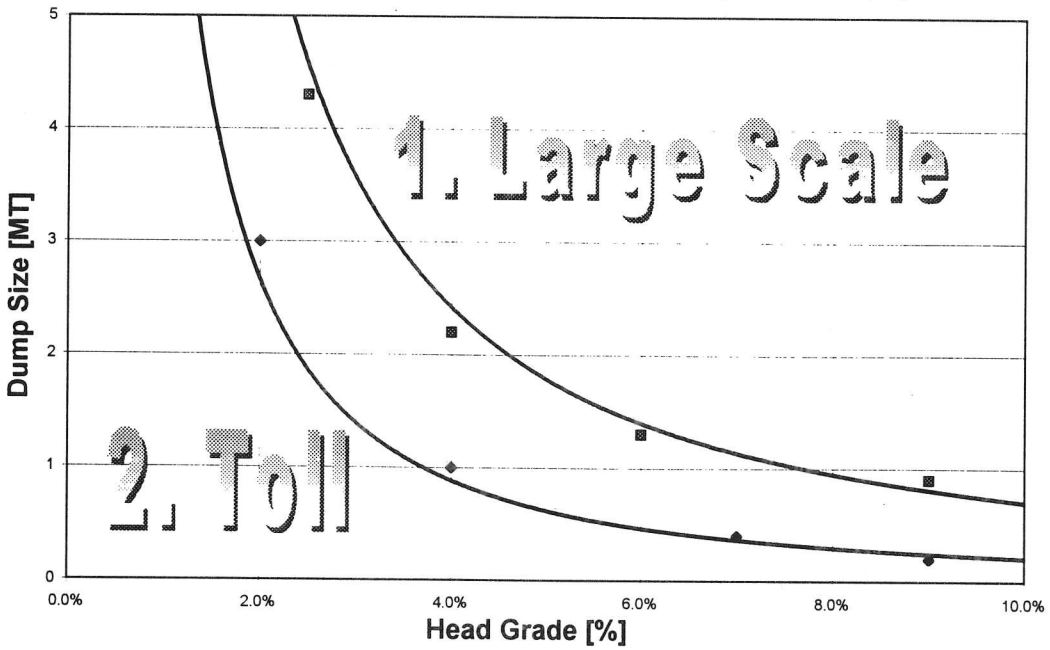

Fig. 4. Factors affecting Jigging applications

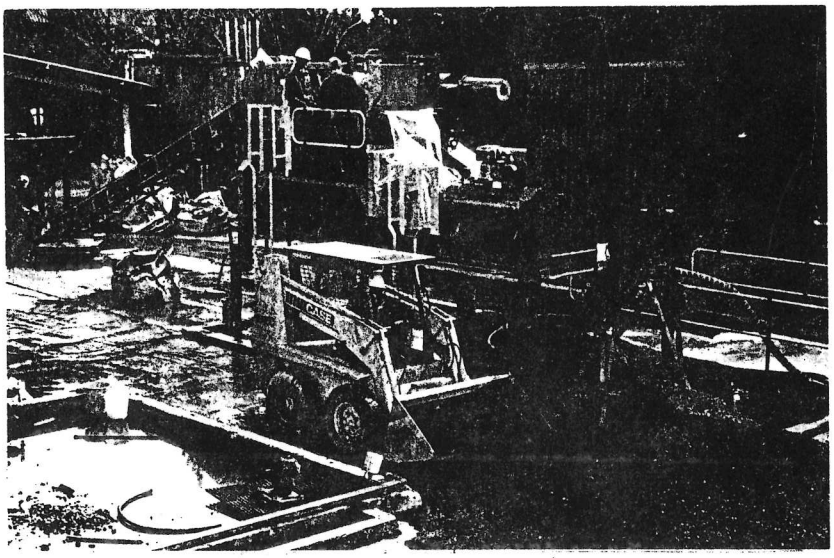

Fig. 5. Commissioning of a Toll Treatment Apic Jig

Other areas of application

Jigging technology has only recently been applied to the recovery of ferro-alloys. As it is a gravimetric separation, it's application can be expanded into other related areas.

To date it has been successfully implemented on Mn ore upgrading and testwork has shown it to be applicable to iron ore upgrading. Further test have shown FeV, FeNb and stainless steel slags are also amenable to jigging.

As previously stated, the choice for producers of Toll Treatment versus own and operate will ultimately depend on client preference and market value of the entire resource.

Conclusions

This illustrates an exceptional example of where a research organisation and a project management and engineering company have worked together successfully to implement a technology from research and development stage to final commercial realisation.

New areas of technical improvement are continually being sought with a view to expanding the range of application of the technology.

Production companies are being given different scenarios for reprocessing, depending on their specific conditions and needs. While large scale client operated plants are appropriate in some cases, toll treatment facilities are becoming more attractive.

Cogniscence has been taken of prevailing market conditions and traditional solutions such as large scale turnkey plants are still offered, whilst offering the concept of toll refining to those clients whose financial or physical requirements dictate otherwise.

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