THE DEVELOPMENT OF AN AGGLOMERATE THROUGH THE USE OF FeMn WASTE

K.P. Davey

[1]ASSMANG Cato Ridge Works, Eddie Hagan Drive, South Africa. E-mail: keithd@feralloys.co.za

ABSTRACT

In 1998 an initial objective was given to the author, to process valuable off grade High Carbon Ferro Manganese (FeMn) metal fines profitably. The previous attempts that had been made to re-melt these metal fines through the furnaces had resulted in poor furnace operation, mainly to do with lack of electrode penetration and furnace bed permeability. It was decided that the method to resolve these problems was to agglomerate the metal fines.

During the study on the agglomeration of the metal fines, a decision was made to use furnace baghouse dust and stockpiled furnace baghouse dust and sludge (DSF) as a "filler" in the metal fines. The primary reason for using baghouse dust was to eliminate an environmental hazard, whereas the secondary reason for using the DSF was to utilize manganese units contained in the dust.

The off-grade metal fines and dust were compacted using a brick press, with cement and aluminum rich plastic clay as a binder, to obtain agglomerate that was cost effective.

Through the re-melting of the agglomerated off-grade metal fines, it was realized that this agglomerate concept could have other uses, that of replacing ores on the furnace, at a lower cost. The agglomerate recipe was changed to create an agglomerate that had a high manganese to iron ratio, this replaced Comilog ore on the furnaces, thereby reducing overall furnace unit costs.

Future work concerning agglomeration, is to reduce furnace costs further through agglomerating –0.5mm ultra ore fines and –0.3mm Gloria and Nchwaning sludge. Using this agglomerate replaces a portion of the Gloria and Nchwaning lumpy ore on the furnaces at a lower cost. This would eliminate problematic material that exists at the ASSMANG Manganese mines.

LEGEND

Due to the fact that various abbreviations on raw materials are used in this report, it was thought necessary to provide a legend to facilitate a better understanding of the raw materials that were used in the manufacture of the agglomerate. The legend will also provide an explanation of products manufactured.

DSF refers to furnace baghouse dust and sludge recovered from the slime dams, which have been stockpiled on site at the Cato Ridge Works. This material which is exposed to the elements, has a moisture content of + 30%. The metal value in this dust and sludge is in an oxide form.

Furnace dust is baghouse dust that is currently generated from the furnaces, and recovered directly from the baghouse silo's. It has a low moisture value. The metal value in this dust is in an oxide form.

CRA dust refers to Cato Ridge Alloy's (CRA) dust. CRA produces low and medium carbon ferro-manganese via an oxygen blow. The dust generated from this process is used as an addition to the agglomerate called SD-ore. The metal value in this dust is in an oxide form.

SD ore is SupaDupa ore, which is an agglomerate. It consists of 20% metal fines, 36% furnace dust and DSF, 34% CRA dust and 10% binder.

K Ore   Is Keith ore, which is an agglomerate. It consists of that of 67% metal fines, 26% furnace dust, DSF and 7% binder.

1. INTRODUCTION

ASSMANG: Manganese Cato Ridge works had two problematic materials that had to be re-processed through the furnaces. The first material consisted of approximately 20 000 tons of valued off-grade ferromanganese (FeMn) fines. The second material was approximately 90 000 tons of stockpiled dust and sludge (DSF) which had been generated from the furnaces over a period of 45 years.

The following report will discuss the development of the agglomerate, in being utilised to re-process valued off-grade ferromanganese metal fines through the furnace, to the stage where the agglomerate has been developed to replace manganese bearing ores on the furnace at a profit to the company. While at the same time eliminating an environmental hazard posed by the 90 0000 tons of stockpiled dust and sludge.

The report will also discuss manufacture methods, specifications of the agglomerate that are important to consider when agglomerating material and impact of the agglomerate on the furnace operations.

2. INITIAL OBJECTIVES FOR PRODUCING AN AGGLOMERATE

The primary reason for the introduction of the agglomerate into the Cato Ridge Works was to:

- Convert 20 000 tons of valuable, but un-saleable off-grade metal fines (-67% Mn) to a saleable lumpy product.
- To produce the agglomerate as cheaply as possible, with minimal capital cost.

3. SPECIFICATION FOR THE AGGLOMERATE

Prior to the manufacturing of the agglomerate, it was anticipated that the agglomerate would have to meet certain criteria, namely:

- A certain cold strength was required, so that the agglomerate would not break down in the raw material handling system feeding the furnaces.
- The material should have an adequate hot strength, so that it would be able to penetrate into the furnace burden without breaking down.
- The material would have to be correctly shaped, so that it would not block discharge vibrators, or roll down the raw material conveying systems.

4. MANUFACTURING METHODS

In the agglomeration of the metal fines, various options were considered but were hindered by financial constraints. It was decided to have the agglomerate “blocked’ into bricks by a contractor who’s bricking plant was located some 18 kilometre’s distance from the Cato Ridge Works plant.

In order to proverbially “kill two birds with one stone” and thus begin to eliminate an environmental hazard, it was decided to use a portion of the 90 000 tons stockpiled baghouse dust and sludge (DSF) and fresh baghouse dust generated from the furnace’s to act as a filler in the agglomerate.

The reason for the baghouse dust and DSF selection as a “filler” were:

- It varied from the particle size of the metal, and through its addition the packing density of the agglomerate could be optimized.
- It contained a manganese value of approximately 33% and a high manganese to iron ratio of 16 (this means that the iron content of the dust is approximately 2%), which would be beneficial in furnace manufacture of HC FeMn.
- Baghouse dust and DSF material addition to the metal fines increased the resistivity of the agglomerate, promoting electrode penetration.
- The baghouse dust and DSF is pozzylanic in nature therefore reducing the overall binder addition, which would reduce the cost of manufacture.

- It has zero value in the Works accounting system, therefore through the addition of this material to the fine metal (which has value) it would reduce the overall cost per ton of agglomerate.
- The potential environmental problem caused by the leaching of stockpiled baghouse dust and sludge would be addressed by re-cycling this material through the furnaces, which would eliminate a long term environmental storage facility at Cato Ridge.

The blocking plant set up at the contractors site, had to be modified in order to accommodate the stockpiled DSF as the material had been compacted and tramp material was present in the stockpile.

The set up of this blocking plant is the following.

- Material is fed into two hoppers, which have a 20mm vibrating screen located over a hopper in order to remove tramp material.
- The metal fines and dust is bottom fed onto a conveyer which feed a skip loader situated on loadcells.
- Addition of binder occurs at this skip.
- The skip is then used to feed an Eirich mixer. It was deemed necessary to have an Eirich mixer in the circuit as high intensity mixing was a requirement with the two materials having such different densities.
- At the mixer water addition would be determined. The process had to be a batch process as the moisture content varies considerably in the raw materials, with fresh dust having a moisture content of 1 to 2% while the stockpiled DSF has higher moisture contents of over 30%.
- The material then moves into the VB2 block making machine where high intensity vibration assists in ensuring that the material completely fills a fixed mould.
- The material in the moulds is tamped down via the tamper heads of the block machine and is then removed via a conveying system.
- A pallet with the agglomerate is then removed off a conveyer by hand, and stacked.
- This is the point at which curing time and strength is optimised, as the material on the pallets is then stacked and air-dried for a period of 12 to 24 hours. Once the material is sufficiently cured it is stockpiled for a further 24-hours to air dry and finally removed to Cato Ridge to be processed through the furnaces. Altogether 48-hours is required for the material to have sufficient cold strength (15 to 20 MPA) to survive the Cato Ridge raw materials batching system

The agglomerate produced was called K-ore (Keith) and would be used as an ore replacement on the furnaces.

4.1 HOT and COLD strength of the K-ore

The cold strength of the agglomerate was determined by the raw materials handling system. A series of drop tests were conducted to imitate this raw material system. The K-ore was deemed to have sufficient hard strength if the –5mm material obtained after these drop tests was below 10%. With the addition of 4% cement it was found that the K-ore had sufficient cold strength to manage the raw materials system. The curing time of this agglomerate was 72 hours, and it was also found that with the increase of cement addition the curing time lengthened. The importance of curing time is dealt with under heading 4 “MANUFACTURING METHODS”.

The hot strength of the K-ore, bound with cement was tested in a muffle furnace. The K-ore was thermally bracketed between 200 °C and 800 °C. The reason for doing this was to ensure that the material would be able to penetrate into the furnace burden deeply enough, so that little material would be lost to the furnace gas off-takes, once furnace trials started.

With every 200°C increment, a block of K-ore was removed from the muffle furnace and dropped from a height of 2 meters to establish whether the K-ore was competent or not. It was determined that the cement bound K-ore degraded and become exceptionally friable at temperatures above 400°C. This is where the tri-calcium silicate bonds break down. Due to the fact that cement was found to be inadequate as a binder when considering hot strength, it was decided to test an alumina rich fondue cement. The fondue cement increased the hot strength of the product, but did not provide adequate cold strength. The cost of a fondue cement was expensive however, which would drive working costs up, which would in turn mean that the objective of producing an inexpensive agglomerate would not be met.

It was decided at this stage to manufacture Cato Ridge's own fondue cement by combining cement and plastic clay as binders into the agglomerate. The addition of an alumina rich plastic clay and cement has the following advantages, namely:

- The presence of cement and alumina promotes flash setting, so that material sets initially to provide an adequate initial handling strength within 12-hours and a good cold strength within 48-hours.
- The cement provides the adequate cold strength to 400°C.
- The tri-calcium aluminate bond promotes adequate hot strength to over 800°C. In fact this material has handled temperatures as high as 1400°C in an oxidising atmosphere.
- The cost of the plastic clay was approximately 50% cheaper than the fondue cement, and would keep working costs within budget.

It was also found that by varying the addition of the raw material to the K-ore the cold strength of this material could be optimised. The approximate recipe for the K-ore is seen in table 1: (This recipe was to vary marginally as sizes of the DSF and metal fines changed.)

Table 1. K-ore ore recipe.

Composition	**Percentage**
Metal fines	67%
Furnace/DSF dust	26%
Plastic Clay	3%
Cement	4%

4.2 Shape of agglomerate

The shape of the agglomerate appears to be an arbitrary matter, but if a agglomerate is manufactured, and cannot be fed into the furnace the development of the agglomerate is pointless.

Large blocked K-ore would hang up in the feed chutes and raw material bins.
Small blocked material would not be viable for manufacture, as this would decrease production throughput and not make it financially viable for a contractor.
Cylinders would roll off a conveyer.

The only sensible option is to manufacture half cylinders, which do not roll off conveyers and do not block the raw material bunkers. The dimensions for the half cylinders are as follows:
50mm diameter X 50mm height.

5. COST IMPLICATIONS AND PERFORMANCE OF AGGLOMERATE

5.1 K-ore

Table 2. Analysis of K-ore.

Analysis	**Percentage**
Mn	56.20%
Fe	9.84%
SiO2	4.46%
CaO	3.63%
MgO	0.58%
C	6.28%
Al2O3	1.83%
Mn/Fe ratio	6/1

5.2 Furnace performance

The K-ore was tested on furnace 3, an 11.5 MVA furnace. The K-ore was used to replace 6% of Nchwaning and 4% of Gloria ore. In total 10% of the ore feed to the furnace was K-ore as a test on the furnace. In the test phase electrodes did not climb out of the furnace, as is usually associated with metal fines addition, and in addition, furnace bed did not sinter up.

Table 3. Furnace Performance with K-ore.

	Ore/ton alloy	MWH/ton alloy	Fixed carbon/ton alloy
With K-ore added	Decreased 10.4%	Decreased 7.4%	Decreased 11.4%

Table 4. The Effect of K-ore Addition on Furnace Production Costs.

	Ore Cost/ton alloy	Reductant Cost/ton alloy	Flux Cost/ton alloy	Power cost/ton alloy	Paste Cost/ton alloy	Total Cost/ton alloy
K-ore	Increased 2%	Decreased 9%	Decreased 1%	Decreased 7%	Decreased 14%	Decreased 3%

Once the K-ore had been tested on one furnace and shown to work, the material was used on other furnaces.

5.3 The Performance of other Furnaces

Furnace one and two are 22.5 MVA open furnace. An average of 9% K-ore (as a percent of ore feed) was used on furnace 1, while an average of 6% K-ore was used on furnace 2.
Furnace 6 is a 24.5 MVA closed furnace. An average of 6% K-ore was used on furnace 6. Table 5 will highlight these furnace's performance, with and without K-ore.

Table 5. Furnace Performance Comparison – With and Without K-ore Addition.

FURNACE With K-ore	MWh/ton	Ore/ton	Average metal Tons	Difference in Availability (before) – (during K-ore)
Furnace 1	Decreased 6.7%	Decreased 2.4%	Increased 3.5%	On Par
Furnace 2	Decreased 4.4%	Decreased 6.1%	On par with no K-ore	Decreased 2%
Furnace 6	Decreased 6.3%	Increased 1.9%	Increased 21.3%	Increased 2%

The K-ore addition to the furnace appeared to stabilise furnace 6, reduced long slips on electrodes and improved furnace 6 availability. The reason for a 21.3% increase in production on furnace 6 can also be attributed to less electrode breakage during this evaluation period. Therefore the K-ore performance on furnace 6 is not a true reflection as depicted in Table 5.

Though it was found, in later investigation that the K-ore assisted in maintaining electrode length in the furnace, as consumption on electrodes decreased with the addition of K-ore without the loss of electrode length.

5.4 Environmental hazard

With the use of K-ore fresh baghouse dust and stockpiled dust and sludge will be re-processed through the furnace, so addressing the current environmental hazard that exists.

An average of 30 tons/day of K-ore was manufactured over the period of a year for furnace feed. This meant that approximately 7.8 tons of dust and sludge was being recycled back to the furnaces each day.

The current arisings of baghouse dust in the Cato Ridge plant amounts to 9 tons per day.
The current arisings of sludge are 3.1 dry tons per day.

The addition of material to the dumps and slimes dams had thus slowed down, but K-ore could not address the total volume of dust and sludges and therefore remove a potential environmental hazard.

6. SECONDARY OBJECTIVES FOR PRODUCING AN AGGLOMERATE

The strategy on K-ore has changed, after operating for approximately a year on this material. This was due to:

- The off-grade metal fines that were being depleted.
- The environmental hazard of 90 000 tons of DSF that still existed on site.

It was also at this stage that 15 000 tons of stockpiled converter dust was made available from Cato Ridge Alloys (CRA). CRA is a subsidiary company of ASSMANG Cato Ridge Works. It is a converter operation, which produces low, and medium carbon FeMn via an oxygen blow. The dust generated from this oxygen blow has the following analysis as seen in Table 6.

Table 6. Analysis of CRA (Converter) Dust.

Analysis	Percentage
SiO2	3.51%
Fe2O3	3.71%
MnO	91.19%
Mn/Fe	27/1

The manganese content of the CRA dust existed mainly in a Mn3O4 form, with small amounts of MnO being present and well as small quantities of metal.

This material would be purchased at a price that is bench marked with international prices.

With changing strategies and with new raw material available new objectives were set, these were:

- To reduce production costs of K-Ore agglomerate through using a higher quantity of zero cost baghouse dust and DSF in the recipe, thereby continuing to address the environmental hazard.
- With the high Mn/Fe ratio and Mn content being made available from the CRA dust, one of the objectives was to produce an agglomerate which would replace Comilog ore (C-ore) which has a Mn value of 50% and a Mn/Fe ratio of 25. The C-Ore value is on average almost 400% more expensive than other ores used on the furnaces. This would decrease the furnace feed cost/ton of FeMn produced.
- To increase FeMn production.

7. ADJUSTED MANUFACTURING METHODS

The same method as mentioned under heading 4 "manufacturing methods" was used to manufacture the agglomerate. The CRA dust was simply added from an additional bin positioned at the Skip loader.

CRA dust has no binding properties because it does not have sufficient levels of SiO2, CaO and MgO, and as a result the cold strength provided by the binders used in K-ore was not sufficient. This problem was overcome by increasing the additions of cement and plastic clay by 2% and 1% respectively.

The agglomerate was called SUPADUPA (SD) ore.

Table 7. SD-ore Recipe.

Composition of SD-ore	Percentage
Metal fines	20%
Furnace/DSF dust	36%
CRA dust	34%
Plastic Clay	4%
Cement	6%

Table 8. Average Analysis of SD-ore.

Analysis	Percentage
Mn	48.21%
Fe	4.44%
SiO2	1.70%
CaO	0.7%
MgO	0.3%
C	11%
Al2O3	2%
Mn/Fe	11/1

If the addition of metal fines to the SD-ore is ignored, then the Mn/Fe ratio of the SD-ore is 20
The cost to produce SD-ore was substantially lower than the cost of Comilog ore. (less than half the cost).

8. SECONDARY COST IMPLICATIONS AND PERFORMANCE

8.1 Furnace performance

An average of 7% SD-ore replaced 6% C-Ore on furnace 5 with the following results, as shown in Table 9.

Table 9. Furnace Performance with the Replacement of C-Ore with SD-ore.

	MWh/ton	Ore/ton	Average metal	Difference in Availability (before) – (during K-ore)
SD-ore (No C-ore addition)	Decreased 3.1%	Increased 0.5%	Increased 2.8%	Increased 0.6%

The SD-ore reduced production costs by approximately 10%. This material was only used on the furnace for approximately 2 months before metal fines stocks were depleted. The metal fines were replaced with crushed scrap fines. Scrap refers to material that has a reasonably high metal content, but this metal is entrained in slag.

8.2 Environmental hazard

Furnace dust and DSF material would be re-processed through the furnaces in higher quantities via the SD-ore route. The extent to which the environmental hazard was addressed was once again determined.

An average of 40 tons a day of SD-ore was manufactured. This meant that approximately 14.4 tons of dust and sludge material is being recycled back to the furnaces.

This exceeds the current arisings by 1.3 tons. With the help of SD-ore a similarly manufactured ore, Cato Ridge Works is reclaiming the dust and sludge stockpiles and in addition consuming the current arisings.

SD-ore can address the environmental hazard at a faster rate than K-ore, if production of the SD-ore is increased.

9. FUTURE OUTLOOK FOR AGGLOMERATE

The following will be discussed under this heading:

- The future of SD-ore type agglomerates.
- The present infrastructure for agglomerate manufacture.
- The possibilities of creating designer ores, for a furnace.

9.1 The future of the SD-ore type agglomerate

Stocks of metal fines have been depleted to a level where the SD-ore is utilising metal rich scrap to replace metal in the agglomerate recipe. Metal fines and/or scrap is essential as a raw material in the manufactured ore as it optimises packing densities due to the sizing of the material. The availability of this metal rich scrap limits the manufacturing rate of the SD-ore to approximately 40 tons a day. This manufacture rate will mean that the DSF stockpiles of 90 000 tons will only be eliminated over a period of 189 years. Other material had to be located, which would substitute the scrap, in order to increase production of the SD-ore.

Other raw materials that are available, which are in the same size fraction range as the metal fines and scrap, are:

- N-Ore fines (–9 X 0.5mm)
- N-Ore ultra fines (-0.5 X 0.05mm)
- N Ore sludge.

The only problem with utilising the N-Ore fines is that it has a poor Mn/Fe ratio of 4 and it also has a lower Mn content than the Nchwaning lumpy ore. As a result of this, spiralling tests using heavy mineral concentrate spirals were initiated in an attempt to upgrade the ultra fines and sludge, which also has a poor Mn/Fe ratio and low Mn contents.

Through spiralling this material, the Mn/Fe ratio was upgraded to above 5 and the Mn content increased to be on par with the Mn content of the lumpy ores. It is anticipated that through blending the upgraded sludge and ultra fines with the N-ore fines, a reasonable Mn/Fe ratio and Mn content can be obtained from this material. This material can then be used to replace scrap and metal fines in the manufacture of an agglomerate, therefore increasing the manufacture rates.

Agglomerates have been successfully produced with these raw materials, but the material has not as yet been tested on the furnaces.

9.2 Present infrastructure for agglomerate manufacture

Studies have been completed to establish a sinter plant on site at the Cato Ridge Works. This sinter plant would then re-process all current arising of dusts and sludges and the DSF stockpiles. This is the primary reason for not moving the blocking plant to Works, as Cato Ridge cannot enter a long-term contract with a contractual supplier without a steady supply of raw material.

Until a decision is made concerning the sinter plant, present arrangements and infrastructure are to remain as is.

9.3 The creation of designer ores

Further studies and investigations are being carried out into creating designer ores. These studies include.

- Designing an exothermic ore, through the addition of aluminium or MnO2 into the agglomerate.
- Using the agglomerates as carriers of carbon into the furnace, thereby optimising the power factor on a furnace.

10. CONCLUSION

- K-ore the agglomerate was successful in re-processing 20 000 tons of off-grade FeMn metal fines through the furnace while reducing furnace costs by 3%.
- SD-ore is successful in reducing the present stockpiles of DSF on site, while reducing furnace costs by approximately 10%.
- The availability of metal rich scrap limits the production of SD-ore to 40 tons a day.
- SD-ore will be able to re-process the DSF dumps and all current arising from the furnaces over a period of 189 years at present rate of production. A faster method to re-process these dumps is desired.
- Other agglomerates have been made successfully using N-ore ultra fines and spiralled ore sludge, these agglomerates have not as yet been tested on the furnaces. Through substituting these materials for scrap in the SD-ore recipe production throughput of the SD-ore will increase.

11. ACKNOWLEDGEMENTS

J. Davey for her support, G. Weddel for making the products, R. Burger for supporting the idea and ASSMANG, Manganese for permission in publishing this paper.

12. RECOMMENDATIONS

It is recommended that the present method of agglomeration, used by the Cato Ridge Works be continued as it is capable of resolving an environmental hazard profitably, through turning a waste material into a valued albeit synthetic ore.

It is further recommended that the agglomerates made with ultra ore fines and ore sludge, be tested on the furnaces, to evaluate if furnace costs can be reduced further, and to eliminate the DSF stockpile at a quicker rate.