BENCHMARKING IN THE FERROMANGANESE PRODUCTION PROCESSES

B Kaelo Sedumedi[1], Dr Xiaowei Pan[2]

[1] Department of Metallurgy, University of Johannesburg, ksedumedi@vodamail.co.za
[2] Department of Metallurgy, University of Johannesburg

Abstract

Process benchmarking is recognised as an essential tool for the continuous improvement of the quality of products. It is a process that allows the production of manganese ferroalloys i.e. ferromanganese and silicomanganese (FeMn and SiMn) to improve upon existing ideas and practices. In this study, it is critical to interrogate the organisation of production of manganese ferroalloys in the identified production plants. Three production plants were identified within, and two outside South Africa. A methodology of research was identified that will be most appropriate to undertake the study. From the research process, it is expected that the critical variables that impact on production processes, differences in application, scale of processes, measurement methods, and competitiveness analysis to be identified.

Benchmarking, Ferromanganese, Silicomanganese, Measurements Metrics, Production Metrics, Production Indicators

Introduction

There have been fluctuations in the manganese ferroalloys market due to the consumption turbulences in the steel and iron ore commodity pricings. It then necessitated an insight into the technological processes used by ferromanganese producers. The potentiality exists to examine shared applications like the furnaces, energy requirements, better materials handling and preparation techniques, mobility of labour, monitoring procedures, and research initiatives (Jones, T, 1994).

Benchmarking is a process of improving performance by continuously identifying, understanding, and adapting outstanding practices and processes found inside and outside the production facility. It is usually treated as a structural process. Developing a step-by-step model best provides the organisational and operational structure for benchmarking. Any type of benchmarking process model should provide an adequate framework for the successful planning and execution of a benchmarking exercise. It should be flexible enough to encourage the ferromanganese (FeMn/SiMn) operation to modify the process to suit its needs and project requirements (Dattakumar and Jagadeesh, 2003).

Production managers of FeMn/SiMn operations are continuously searching for techniques that enable quality improvements. Benchmarking is one such technique that has become used in the recent times. Though benchmarking is not new, it has now found widespread consideration among decision-makers. There are different types of benchmarking and not all of them would be relevant to a metallurgical production process environment. But there is always an opportunity to derive also a useful benchmarking inferences from other best practices outside the ferromanganese industry.

Benchmarking is not about making changes and improvements unintentionally, but it is about adding value to a FeMn/SiMn production process environment. No FeMn/SiMn production process should make changes if the changes are of no qualitative consequence. When using benchmarking techniques, it should be observed during furnace operation how processes in the value chain are performed (Sweeney, 1994):

a. Identifying a critical process or sub-process that needs improvement;
b. Identifying a productive unit that excels in the process, preferably the best;
c. Contacting the excelling unit and/or organisation that you are benchmarking for a visit to study the process or activity;
d. Analysing the data; and
e. Improving the critical process at the operation.

Process Benchmarking

The organisational practice of benchmarking was pioneered by Xerox through the reverse engineering of products of other industry players in the copiers market in the late 1970s. In our context, benchmarking is performed by ferromanganese organisations to improve performance over time. It is broadly regarded as a process of identifying, understanding, and adapting outstanding practices from any organisation to help another organisation improve its performance and outcomes. Up to the year of 2000, there were about 480 academic inputs focusing on benchmarking (Dattakumar and Jagadeesh, 2003). And it is regarded as the practice of being humble enough to admit that another organisation somewhere is better at something, and being wise enough to learn how to match or even surpass them in this matter. But the performance and outcomes have to be informed by the FeMn/SiMn production process in this study as illustrated by reactions of Figures 1 and 2. The general motto followed is as follows: Average is the bottom of good and the top of bad (Dattakumar and Jagadeesh, 2003; Jetmarova, 2011).

Figure 1: Manganese ore transformations under air

$$\mathbf{MnO_2} \;\underline{\;\;500^0C\;\;}\; \mathbf{Mn_2O_3} \;\underline{\;\;900^0C\;\;}\; \mathbf{Mn_3O_4} \;\underline{\;\;1700^0C\;\;}\; \mathbf{MnO} \;\underline{\;\;1700^0C\;\;}\; \mathbf{Mn}$$

And different Mn ore transformations have the following stoichiometric reactions in detail:

Figure 2: Reactions of Mn ore transformations

(1) $2MnO_2 + CO(g) \Rightarrow Mn_2O_3 + CO_2(g)$………………▲$H^0_{298}$-99.9kJ

(2) $3Mn_2O_3 + CO(g) \Rightarrow 2Mn_3O_4 + CO_2(g)$…………▲$H^0_{298}$-31.3kJ

(3) $Mn_3O_4 + CO(g) \Rightarrow 3MnO + CO_2(g)$……………▲$H^0_{298}$-16.9kJ

(4) $MnO + C(s) \Rightarrow Mn(s) + CO(g)$……………………▲$H^0_{298}$246.8kJ

The above reactions (1) – (3) are kinetically controlled for an optimal outcome of producing FeMn/SiMn, and (4) by the thermodynamic environment.

Summarily it could be said that benchmarking is a systematic and disciplined process of examining your own processes in the following manner:

(a) Finding who is better or best;
(b) Learning how they do it;
(c) Adapting it to your organisation;
(d) Implementing it; and
(e) Doing it continuously.

In the same vein, benchmarking is not:

(a) Only competitive analysis and benchmark cataloguing;
(b) Number crunching;
(c) Site briefings and observations;
(d) Just copying or catching up;
(e) Spying; and
(f) Quick and easy.

Production Metrics

Due to the rapid growth in its steel production, China has become the most important market for manganese and ferromanganese. To date, it has imported manganese ore rather than FeMn/SiMn, mostly from South Africa. It remains a sizeable exporter of manganese alloys, although the government is discouraging conversion agreements for reasons of environmental protection. Furthermore, the Nikopol plant in Ukraine is an important factor in the world market due to its sizeable capacity of 1.3 m tonnes per annum (tpa). In 2005-2006, the Government of Ukraine attempted to re-nationalise the plant. A dispute between the majority owner Interpipe and the minority shareholder, Private Intertrading disrupted production over the past few years, and played a role in the tight market (Jones, R, 2007; Olsen et al, 2007).

Much of the capacity in mainland Europe has closed over the past two decades, with Eramet's France plant closing in 2003. In Norway, the manganese alloy plants are increasingly focusing on special grades. A limited number of global mineral resource groups continue their hold on high-grade manganese ore reserves, though black-economic-empowerment initiatives in South Africa may lead to new market entrants in the near future. It is can be observed that the Mn ore producers have generally been reluctant to invest in the development of ferromanganese facilities over the past decade or so (Jones, T, 2007).

The basic assumption is that the objective of ferromanganese (FeMn) and silicomanganese (SiMn) producers is to maximise profits. The gain or profit is calculated as being the difference between the value of the produced products i.e. the product value, and the value of the factors of production or costs used. This objective is often called simply profit maximisation. Based on the assumption of profit maximisation, three classical economic issues related to the act of FeMn/SiMn production can be identified (Olsen et al, 2007; Rasmussen, 2013):

(a) What to produce?

The producer usually has the option of producing alternative products with the available production plant. The producer may choose to produce one product e.g. the standard product which is the high carbon ferromanganese (HC

FeMn); or may produce a combination of HC FeMn, silicomanganese (SiMn), low carbon ferromanganese (LC FeMn) and/or medium carbon ferromanganese (MC FeMn).

(b) How much of FeMn/SiMn to produce?

A production process can be carried out more or less intensively. Products can be manufactured using a larger or smaller amount of input materials. The size of the production will depend on this. But what is optimal? To add more inputs like Mn ore, fluxes and reductants, which would result in a large production, or to add less, which would result in reduced costs?

(c) How to produce FeMn/SiMn?

A product can often be produced in several ways. For example, it is possible to reverse undesirable elements by introducing certain fluxes or optimal tapping methods can be used, or appropriate casting cooling methods should also be considered for better crushing and screening of ferromanganese. But what choice would be optimal? What kind of input would result in the lowest costs? Time is also an important factor. How will the blending of the Mn ores and reductants be done to improve the kinetics of the Mn ore reduction to achieve the required optimal results.

In general when speaking of production and related economic issues it is often assumed that the functionality of a ferromanganese production plant is given. If this was the case, the key economic issues concerning production would be related to the question of how to best utilise a given production plant. For example, should the process engineer use the blended or unblended Mn ore, and with which combination of reductants and fluxes?

In practice the production metrics and economic issues concerning production are not well-defined with respect to benchmarking. It is of course possible to make changes to the given production plant, either by investing in new production facilities, or by renting or leasing some aspects of the production facilities. The functional areas of managing the waste materials could be viewed along the same lines as other factors of production, and the issue of how much waste management efforts it would be optimal to apply is in principle also an entirely ordinary production metrics and an economic issue. Whilst it is possible to be considerate of this important principle, when it comes to decisions which have long term implications and concern the production framework, such issues are traditionally discussed when purely focusing on investment and financial planning.

There is no clear-cut distinction on how and when in the theory of production the fixed asset and the related fixed costs become variable. A description of the theory of optimisation of production is based on the assumption that the price of inputs and outputs are determined by external factors and cannot be influenced by the producer. And the FeMn/SiMn producer would be regarded as a price taker in this context. However, a generalisation of the theory to account for conditions in which prices are not constant but dependent on the size of the production could be worked out. Generally, there are no real problems in deriving principles for production optimisation under conditions in which prices are not fixed, i.e. they depend on the quantity produced. However, in this context, the problem of the pricing of output becomes an important subject (Jetmarova, 2011; Rasmussen, 2013).

Interface of benchmarking and production

The interface of benchmarking and ferromanganese production process has to be clarified by the choice of unit of analysis i.e. the process of FeMn/SiMn production. FeMn/SiMn production involves the following functional areas as described above: (a) <u>Materials receiving</u>: raw materials shown primarily as charge feed; (b) <u>Production</u>: processed material shown as recovered metal – HC FeMn, MC FeMn, LC FeMn and SiMn; (c) <u>Waste materials</u>: waste materials would comprise slag, baghouse dust, and slimes from candy filter; (d) <u>Recovery</u>: recycling for further processing like metal from crushing, slag for Mn reprocessing, and dust from baghouse with high Mn content; and (e) <u>Final processing</u>: sale and disposal of FeMn/SiMn to market, aggregate from Metal Recovery Plant (MRP) to construction industry, slimes to dams, dust to dust storage, and waste slag to dump (Olsen et al, 2007). From this explanation, the following table can be formulated:

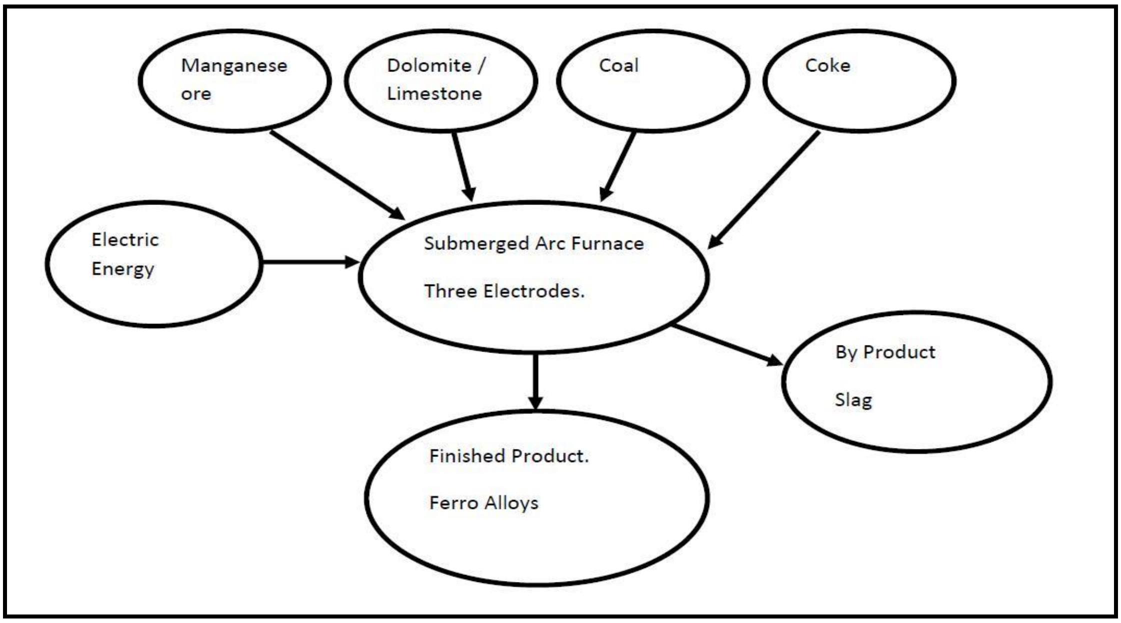
Table 1: FeMn/SiMn functional areas in a typical ferromanganese plant

MATERIALS RECEIVING <u>RAW MATERIALS</u>	**PRODUCTION OUTCOMES** <u>PROCESSED MATERIAL</u>	**WASTE MATERIALS** <u>WASTE</u>	**RECOVERY** <u>FURTHER PROCESSING</u>	**FINAL PROCESSING** <u>SALE AND DISPOSAL</u>
- Mn ore - Coke - Fluxes - Reductants	- HC FeMn - SiMn - MC FeMn - LC FeMn	-Slag -Baghouse dust -Slimes	- Recycling crushed metal - Slag reprocessing - Dust reprocessing	- Marketing - Dust to dust storage - Aggregate to other industries - Slag to dams

As stated as above, the context has to be clarified: the South African Mn ore that is an input material was described as the type of manganiferrous silicate carbonates, and not the oxide type. Where there are oxide types, they are

very marginal and are not economic for large-scale exploitation (Jones, R, 2007). The benchmarking study should in essence explore how easily accessible input materials can be utilised to make the production of manganese ferroalloys competitive in South Africa. A comparative advantage already exists due to South Africa having the largest reserves of Mn ore in the world, which are greatly attributed to the Kalahari manganese reserves (Steenkamp, 2012).
Figure 1 below further simplifies the production process as specified in Table 1. Various functional and sub-functional ferromanganese plant areas should be able to uphold certain quality standards with respect to the required product specifications, materials handling, waste management, recycling procedures, as well as the final sales and disposal of the FeMn/SiMn products. The acceptable quality standards would also in turn create confidence from the product buyers. This would furthermore ensure that the understanding of the ferromanganese production process contributes to the profitability of the organisation.

Figure 3: Overview of FeMn production process



Characterisation of production focus areas

Process benchmarking could be explored if it can develop relevant indicators for production benchmarking given the identified FeMn/SiMn production functional areas. The benchmarking will be biased towards the physicochemical aspects like the functional areas illustrated in Table 1 and Figure 1 above. The thermochemical data could be taken as a constant since there is an established database, and associated phase diagrams have been developed by industrial producers of FeMn/SiMn (Olsen et al, 2007; Tangstad, 2013)

The other form of benchmarking that was relevant for the study is generic benchmarking because FeMn/SiMn is part of a value chain in the steel making process. So the behaviour of the three-phase electric arc furnace also finds application in the production of steel and other ferroalloys like ferrochrome, ferrosilicon, ferrovanadium and ferronickel. There are elements that could be learnt from other ferroalloy producers on the efficiencies of production e.g. the usage of the same facilities for the production of ferromanganese and ferrochrome in South Africa.

Research design

There is very little academic material on benchmarking of ferromanganese production techniques, particularly for a developing country environment such as South Africa. However, the current limited scholarship all concur that the benchmarking exercise is a continuous improvement on product and/or production quality (Dattakumar and Jagadeesh, 2003). There is a large number of benchmarking models, but a methodological orientation in them is not easy. The ferromanganese benchmarking research intends to propose best practices that could be implemented and those that have been observed (Jetmarova, 2011).

This study will be informed by basing its observations and interactions on specific production facilities. Such production facilities would be informed by the production methodologies employed, and could be approached trough two distinct dimensions or a combination thereof:

Benchmarking from a ferromanganese production survivalist perspective:

The leading producers of manganese ferroalloys are also owners or part owners of manganese mines. These producers could have an inward perspective of what could influence their production parameters because the raw materials are of known properties. There has always been availability of good quality manganese ore in countries like South Africa, Gabon, Russia, Australia and Ghana. However, the ore resources would always deplete in terms of quality and quantity in some instances, as a mining and geological reality. The comparative advantage is unnoticeably regarded as the most critical factor of benchmarking by these producers.

Furthermore, the benchmarking indicators in respect of ferromanganese production performance are purely identified as being within the constraints of the organisation. Factors that would be considered here would be the following: reliability of Mn ore from own sources, carbon monoxide (CO) reactivity of Mn ore, enthalpy values for heating and reduction, reduction rate and liquidus of different slags, and carbon dioxide (CO_2) reactivity of carbon materials (Olsen et al, 2007).

Benchmarking from a ferromanganese production competitive perspective:

Ferromanganese producers could also seek learning experiences from other known good producers. It would be an identification of best practices within the sector. In this instance, for example, unknown properties of excellent raw materials could be a preserve of certain FeMn/SiMn producers, bridging effect and permeability of various raw materials, and electrical conductivity of the cokebed surface. The raw materials include good quality reductant and Mn ore (Olsen et al, 2007).

It would be important to consider this benchmarking perspective because it introduces what is not known to a FeMn/SiMn facility. More will be understood about what differentiates one FeMn/SiMn facility from the other. Where appropriate, certain inferences should be made to identify the key indicators that define the benchmarking techniques.

The study emanated from a critical industrial interest and would be a reflection on a particular aspect of FeMn/SiMn pyrometallurgical processes, i.e. general process practice within the producing organisations. It would be a study dominated by empirical research whereby analysis would be deductive, thematic and also based on the methodological approach. Again, the FeMn/SiMn producing South African organisations should form the basis of the study as a key area of research. Based on cases for inference, lessons from other global FeMn/SiMn and ferroalloys facilities will be studied and insights will be accumulated. The dominant research design classification would be empirical, mostly based on numeric, textual, and hybrid data i.e. surveys, secondary data analysis, partly from experimentation done and comparative studies. In this instance, the research environment is of a high control (Mouton, 2001). Therefore, no theory or hypothesis would be formulated; however, the study would also be guided by certain theoretical framework expectations.

DESIGN CONTEXT

Modern FeMn/Si production processes are mature and have basic stages. The added element that needs to be observed is the creation of strongly innovative FeMn/SiMn pyrometallurgical processes which could be influenced by the following four trends: (1) innovation and influx of new technology, (2) pressure of time on the market, (3) increasing customer demands, and (4) globalisation (Brombacher, Sander, Sonnemans & Rouvroye, 2005). It was established that benchmarking was influenced more significantly by best practices controlling strategic implementation of production processes (project selection, goals, technology leadership, product strategy and customer involvement) than by metallurgical processes associated with the execution of benchmarking (process control, metrics, documentation and change control).

Best practices associated with strategic implementation were widely adopted than best practices associated with controlling and executing benchmarking (Dooley, 2000). With that said, the research design aims at developing new methods in benchmarking of the production of manganese ferroalloys, a form of key indicators as a test (Mouton, 2001). Possible limitations would be understood from the context of the methodological studies being largely context bound in the developed countries' environment. Very little methodological research has been carried out in a developing-country environment, although such production was global.

The limitations would thus be how the data has to be sampled to represent actual production phenomena. In such studies, data is collected through standard design types like surveys and experiments. For example, in our study we have the endothermic Bourdouard reaction i.e. $C(s) + CO_2(g) ===== 2CO(g)$, which has well-known recorded variables like the enthalpy of the reaction at $172 kJ.mol^{-1}$. Similarly, $C(s) + MnO(l) ===== Mn(l) + CO(g)$, is a well-recorded exothermic reaction at the metal-slag interface. Therefore, any source of previous research error in the known analysis of the pre-reduction and cokebed zones could be a serious limitation of the methodological research.

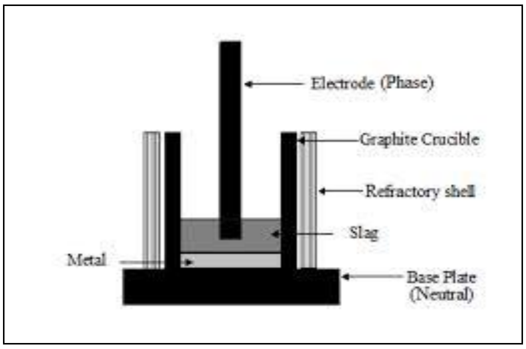
Research process

Process context

The research process is a reference point for the whole methodology of research (Mouton and Muller, 1998). Hence the study was based on an approach to identify the key and/or representative production process environments in South Africa as in the reference cases to be used. Observations will be made and production processes physically surveyed. Secondary material will be collected and transformed into data categories for further analysis and evaluation. Hence, phenomenologically the results would be able to illuminate the specifics of various situations to arrive at a best method(s), which are representative of the FeMn/SiMn production processes. Accordingly, the study will attempt to develop methods through key indicators of how benchmarking can be developed and conducted in South Africa. Therefore, the types of evidence required to undertake the study would require surveys, observations, a collection of historical data for analysis, evaluating of the plant pyrometallurgical practices, the analysis of existing data, and in-depth literature review.

Analysis of data was undertaken by looking at the FeMn/SiMn production process from a technical environment like that in Figure 4. Some of the observations made during the course of the research process should be substantiated by accurately recording each step along the way. A fundamental part of the analysis method in methodological research is the inductive analysis adopted in this study through the evaluation and description of the identified plant production processes. The historical research errors of interviewer and observer effects could be unearthed by using both normal statistical and qualitative forms of data analysis in this methodological study (De Leeuw, 1992).

Figure 4: Ferromanganese furnace view



It is easier to determine accurate definitions and appropriate levels of construct abstraction from multiple cases because constructs and relationships are more precisely delineated (Eisenhardt and Graebener, 2007). Hence, the equipment-producing organisations and mining resources organisations would be investigated for this study, as there will be inferences from other industrial sectors. An integrated design can be followed in a qualitative research design to arrive at a built theory. Its analysis would normally follow the following stages as research develops for a generalisation model (Eaves, 2001):

Activity-by-activity analysis --- Brief Analytical Concepts --- Categories --- Sub-categories --- Linkages among Categories --- Core Theoretical Framework

Empirical data

Here, cases would be divided into three primary and two secondary reference cases and various data would be consulted from various sources in the industry including suppliers of ferromanganese-producing equipments as in Table 2. The five reference cases are a HC FeMn producer, a SiMn producer, a LC/MC FeMn producer, a new HC FeMn producer, and a HC FeMn producer for the European market.

Table 2: 3 x Primary (P) and 2 x Secondary (S) Reference Cases

Reference Cases	Mn ore type	Case Type	Context
1. P1: HC FeMn producer	Braunite II, Rhodochrosite and Hausmannite	Primary Observations SDA	Significant ferromanganese producer in the world
2. P2: SiMn producer	Braunite, Manganite and Hausmannite	Primary Observations SDA	Significant SiMn producer
3. P3: Refined LC and MC FeMn	Pyrolusite (MnO_2)	Secondary SDA Observation	Significant LC and MC FeMn producer
4. S1: HC FeMn producer	Pyrolusite (MnO_2)	Secondary SD	New entrant HC FeMn producer
5. S2: HC FeMn producer	Pyrolusite (MnO_2)	Tertiary SDA	Significant HC FeMn producer for the European market

The semi-structured interviews would be carried out on the primary reference cases. In addition, the secondary data analysis (SDA) and questionnaires would be relied upon with the secondary/tertiary reference cases. Table 2 illustrates how the various data collection methods would be undertaken from the various reference cases. They are referred to as reference cases to illustrate that the emergent theoretical framework would be dependent on theoretical sampling and that the ethnographic research based on semi-structured interviews and questionnaires would be complemented by content analysis of secondary data such as annual reports.

The organisations in Table 2 were chosen on the basis of their uniqueness in respect of the following factors: specific production processes, newness to the market, economic impact, global impact and business profitability. Important questions would need to be asked to achieve best practices in the production of FeMn/SiMn, even though it may not be possible to have all the answers (Maack, 1974; Narayanan, 2000). The process engineer would be requested to respond to the various aspects of the production process, and the background questions (1) to (8) that would be attempted for clarity by observations and requesting for clarity. From best practice studies across various organisations and metallurgical industries, the onsite visits and observations would attempt to understand the reference cases. The standard background questions that influence decision-making in metallurgical organisations for the primary reference would be framed in Table 3 (Cooper, 1993):

Table 3: Typical stage-gate illustration used by ferroalloy industrial producers

Consideration	**Explanation**
1. Customer requirements	How potential customer requirements are identified, defined and changed
2. Product strategy	How benchmarking is aligned with internal constraints and with external factors
3. Concept generation	How candidate concepts for new products are generated or acquired
4. Concept selection	How candidate product concepts are screened and selected for further development
5. Concept design	How the selected concept is designed at a high level
6. Detail Design and Redesign	How product details, materials, and dimensions are specified
7. Manufacturing and Marketing Preparations	How manufacturing processes are developed and channels to get the products to the customers are established
8. Product Improvement and Disposal	How production processes' shortcomings are identified, improvements are made, and how products are disposed of at the end of their life cycle

Reference Cases for study

The study considered the cases as represented in Table 2 i.e. P1, P2, P3, S1 and S2. Other organisations that will be looked at for secondary information would be senior miners, unique producers such as electrolytic manganese dioxide, and exploration companies. There will be a review of the corporate and projects' documents of all the organisations. The choice of organisations identified would set the balance between the nature of ownership of enterprises and the business focus, e.g. between steel-producer owned enterprise, sub-sector focus and size within an industry.

The following aspects informed the context of choosing these cases to assist the study:

(a) The uniqueness of the organisation and/or project: These are unique organisations either in terms of market share, unique operations, and size of a project relative to a developing country environment.

(b) Access to information: It was also focuced on the ease of accessing information through all relevant platforms and most importantly through site visits. Personal interfaces with plant process engineers could also imply participant orientation to the organisation – P1, P2, P3, S1 and S2 in this instance.

(c) Reliability of processes: It was important to use organisations that have established processes at a global scale. These processes could largely be informed by the technological paradigm being implemented. For example, P1 would be focused on HC FeMn processes that are well defined globally.

CONCLUSIONS

The study assisted in gaining insights into the various production processes from the chosen reference cases for measurement metrics. From the preliminary findings, the following can be identified as broad categories and/or production indicators:

<u>Macro-thermodynamic scenario</u>:

It will be important to decipher the physico-chemical properties of the formation of minerals. Particular Mn mineral formation could be considered to be in a state of chemical equilibrium. The mineral compositional data can be explained by thermodynamics with respect of temperature T and pressure P of the mineral equilibrium. State functions can explain the thermodynamic state of the mineral deposits whereby T and P are the prime variables in terms of the following equation:

$$\mathbf{G = U + PV = H - TS}$$

The effects of Mn content in the mineral deposit, level of porosity, and the mechanical strength can be deduced from this macro-thermodynamic environment.

Technology aspects:

It could be observed that the source of innovations of processes' technology has the following primary sources:

(i) Equipment suppliers

Most of equipment suppliers are of service to both the producers of ferromanganese and steel. They serve as a technical conduit between the producers of input materials like Mn ores and steel producers. This motivation empowers the equipment suppliers to be capable pyrometallurgical researchers to develop solutions for the ferroalloy industry. Their focus had to improve the efficiencies of production processes as in the design of furnaces, and the preparation of input materials like Mn ore and reductants. Companies like Metix, Semag, Siemens, and Xi'an Abundance Electric Technology Co. Limited (AEXA) have been able to demonstrate such a research capability.

(ii) Ferromanganese producers

Some ferromanganese producers like Mizushima have been able to provide solutions to their own production processes. And they have formed mergers with companies who have access to high quality Mn ore resources. The technical driver for the research capability is when the shareholder is controlled by a steel producing company.

(iii) External research support

The ferromanganese industry in South Africa was iniated as an entrpreneurial effort. However, historically the mining and metallurgical industries in South Africa have also been assisted by research from institutions of higher learning particularly Wits University and later the University of Pretoria, other research instituions like the Council for Scientific and Industrial Research (CSIR). The industries have also sponsored such research endeavours on pyrometallurgical production processes. Such external research support managed to become a technical conduit between the mining industry, ferromanganese producers and steel makers. It could be demonstrated through the conception of the Iron and Steel Corporation (ISCOR).

Energy aspects:

Electricity is one of the critical cost drivers in a ferromanganese production process especially in South Africa where ther have power cuts. Most of the industry has been on Megaflex accounts when there is high electricity usage, the industry could be asked to switch off their furnaces at a rebate. Hence there have been alternative power generation initiatives have been piloted at various locations, and some as permanent features of the FeMn/SiMn process. Methods that have either been piloted and/or implemented include the following:

- Blast furnace method
- Using thermal coal as an energy source
- Recycling excess capacity
- Decarburisation Coal Injection (DCI) method

Environmental aspects:

There are legislative requirements in operating a ferromanganese plants. Most plants have procedures in place to ensure legal compliance. However the legal compliance does not always translate to environmental friendly procedures. The following have to be thoroughly monitored as both safety and environmental measures:

- Dust suppression
- Dust bagging
- Slag disposing
- Emissions control

Materials handling:

The furnace processes of smelting have to be facilitated by appropriate input materials to improve their reactivity. Mn ore can be stacked and reclaimed for proper grade and quality control. The reactivity particularly of the Mn ore was also enhanced through material handling processes like having permanent stockpile facilities. Importantly were the porosity and mechanical strength of the Mn ore and reductant; as well as the viscosity and resistivity of the slag. Such handling measures were accompanied by the following technical interventions:

- Sinter product preparation
- Mn ore size feedstock preparation
- Reductant size preparation
- Using batch tapping versus continuous tapping at different pouring rates
- Using granulation product instead of ingots or bars

Marketing:

The marketing element could be outside the control of the production process environment. But the soundness of production processes increases the prospects of the saleability of ferromanganese products. The following aspects have to be considered when introducing the product into the market:

- Technical saleability emphasis, and not just big tonnages;
- Sales strategy - collaborations on toll smelting with other Mn ore producers to reduce input costs like energy;

- Trade platform: smelters could be closer to raw materials especially the Mn ore; or export routes for better price influencing;
- Product strategy: there should be flexibility and diversification on how the plant can yield the final product for better production process efficiencies.

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