

Improve Ferromanganese Smelting Processes Using Benchmarking Techniques

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Abstract—it is well known that ferromanganese alloys are used to help produce all types of steels. Manganese ore prices are closely associated with those of iron ore prices. The production of high quality ferromanganese has become increasingly important in the context of fluctuations in the iron ore price in global markets.

In appreciating the importance of benchmarking the various ferromanganese production practices worldwide have to be identified to develop methodological aspects. Firstly the standard production variables would be reconfirmed, and identify new ones given the various sophisticated production environments.

In other words, are there unique variables to specific production facilities? Secondly, appropriate benchmarking method(s) would be recommended given the production objectives in existence. Inductively, all the variables, both metallurgical and non-metallurgical would be condensed into concepts or particular benchmarking techniques.

Keywords—Ferromanganese Production Indicators, Benchmarking Process, Benchmarking Matrix, Benchmarking Types.

I. INTRODUCTION

FERROMANGANESE is produced by the carbothermic reduction of manganese ores, primarily in electric submerged arc furnaces [1]. About 90 – 95 of all the manganese produced in the world is used in iron and steel production in the form of alloys such as ferromanganese and silicomanganese. Manganese has two important properties in steelmaking: its ability to combine with sulphur to form MnS and its deoxidation capacity. Today about 30% of the manganese used in steel industry is used for its properties as a sulphide former and deoxidant. The other 70% of the manganese is used purely as an alloying element [2].

It is the most important feedstock required for the production of high quality steel. Manganese plays a crucial role in the iron and steel industry. As an alloying element, it improves the strength, toughness, hardenability, workability and abrasion resistance of the ferrous products, especially steel.

South Africa is exporting most of its manganese ore, thus benefiting very little into ferromanganese. In the 1980s, the top six ferromanganese-producing countries in the world were

in decreasing order of production China, South Africa, Ukraine, Kazakhstan, Russia, and Norway. The USA and France were the other countries just in the margins [2]. South Africa has since been surpassed by Norway and India. It would be important to understand the challenges of ferromanganese production in South Africa to make it competitive.

The most common ferromanganese is high-carbon ferromanganese and is referred to as standard ferromanganese, and silicomanganese. Silicomanganese became widely used with the invent of secondary production of steel through recycling processes by American steel producers in the 1960s[1].

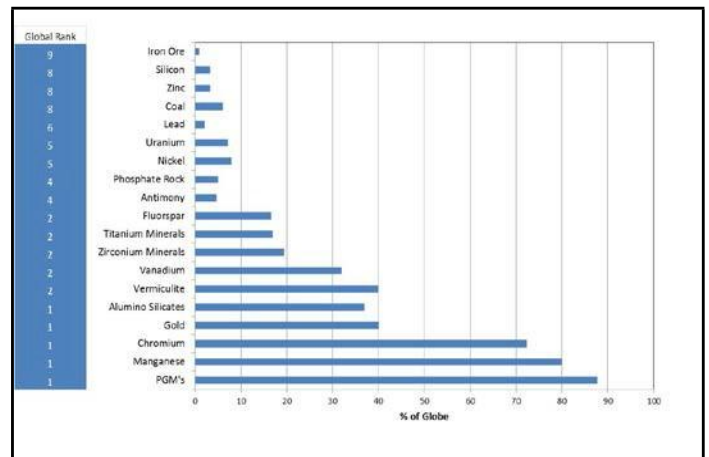


Fig. 1 SA Minerals Reserve, 2008

Manganese ores are classified according to their contents of manganese. In general ores containing at least 35% manganese are classified as manganese ores. Ores having 10–35% Mn are known as ferruginous manganese ores, and ores containing 5–10% manganese are known as manganiferous ores. Ores containing less than 5% manganese with the balance mostly iron are classified as iron ores. Manganese ores are also classified as metallurgical, battery and chemical quality ores. Metallurgical ore is used in ferromanganese or special manganese alloy production or as chemicals. Battery ores are natural or artificial. They are manganese oxide with various purities. Chemical quality manganese ores are classified as group A or group B depending on their manganese, iron and silica contents [1-2].

The initial method used for ferromanganese production was the blast furnace whereby the USA was a leading producer

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before 1945. It could only produce the high carbon ferromanganese (HC FeMn). And it consumed a lot of reductant per metal produced because the carbon source was both a source of power and a reductant. Hence there was a move to roll-out submerged electric furnaces (SAF). Hence From 1977 the USA imported manganese only in the form of ferromanganese and manganese metal [1]. Nowadays, even with the production paradigm of the submerged electric arc furnaces, there are moves to find the most efficient and economic production of ferromanganese operations. Hence there is a need to understand how to influence the process of improving performance by continuously identifying, understanding, and adapting outstanding practices and processes found inside and outside an organisation i.e. benchmarking [4].

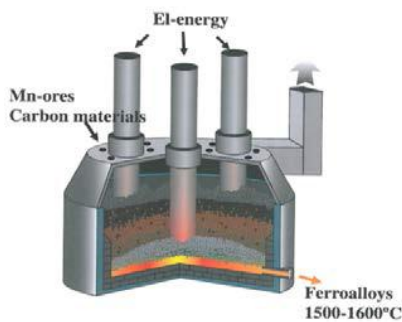


Fig. 2 Typical Ferromanganese Furnace

II. BENCHMARKING PRINCIPLES

Benchmarking is recognised as an essential tool for continuous improvement of quality. It is a process that allows a ferromanganese process to improve upon existing ideas. In order to eliminate myths and misconceptions about benchmarking it is important to know exactly what the relevance of benchmarking is and the different types of benchmarking, the criticisms of benchmarking, and the ethical practices formed. The principles of benchmarking have to be counterposed with the intrinsic economic aspects of the ferromanganese operations. Some of the most important aspects to be considered for counterposing benchmarking against the ferromanganese production processes: transport, raw materials – reductants, fluxes and coal, raw materials handling and storage, handling procedures, furnaces, air pollution control equipment, product handling and storage, energy considerations, occupational health and safety, labour, and management and monitoring procedures[4-6].

Alternative materials, principally alloy scrap and oxide, have gained moderately on ferromanganese use per ton of steel produced during the past twenty (20) years. A decline in unit consumption is significant over the long term for the ferromanganese industry because such a decline moderates any increase in ferromanganese consumption resulting from increased steel production. A combination of factors,

including technology, availability, and price, is responsible for this general decline in unit consumption of the major ferroalloys in steelmaking, particularly the production of ferromanganese.

Customer needs for ferromanganese in alloy and stainless steel for many applications have been and will continue to be strong. The steel industry will continue to improve processing technology to reduce raw material needs and develop steel grades with lower alloying metal content that equals or betters performance, while lowering materials costs. For many steel applications, there are no acceptable substitutes, and their key constituents, high-carbon ferromanganese and silicomanganese, are essential. As technology and industry practices result in more efficient use of ferroalloys, strong demand for metals in construction, the chemical industry, transportation, and household appliances is expected to more than offset any basic reduction in unit consumption. Competition from other materials, such as plastics and nonferrous metals in the transportation sector, would be strong, but the use of lightweight, high-strength steel is expected to keep the ferroalloys industry competitive for many years.

Various types of benchmarking techniques have been identified in the past. There are three primary types of benchmarking that are in use today. These are process benchmarking, performance benchmarking, and strategic benchmarking [4]. Process benchmarking would focus on the day-to-day operations of the ferromanganese facility. It has the primary concern of improving the way processes are performed every day. Some examples of work processes that could utilise process benchmarking are the customer complaint/input process, the delivery timing of ferromanganese product, the order fulfillment process, and the recruitment process [5]. All of these processes are at the front end of the organisation of the production facility. By making improvements at a lower level, performance improvements are quickly realised. This type of benchmarking results in quick improvements to the organisation of production particularly the servicing aspects [6].

Performance benchmarking focuses on assessing competitive positions through comparing the products and services of other competitors. When dealing with performance benchmarking, organisations want to look at where their product or services are in relation to competitors on the basis of things such as reliability, quality, speed, and other product or service characteristics. Here a ferromanganese production facility would adopt the reverse engineering methods of understanding the competitors' products.

Strategic benchmarking deals with the leadership dimension in the production equation. It mostly deals with long-term results. Strategic benchmarking could focus on how the production facilities compete. This form of benchmarking looks at what strategies the facilities are using to make them successful. This is the type of benchmarking technique that most Chinese and Japanese facilities use.

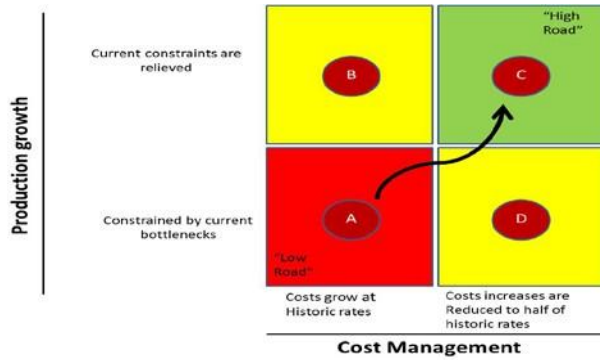


Fig. 3 Ferromanganese production scenarios

This is due to the fact that these facilities focus on long term results and sustainability. In general the benchmarking scope in term of the types is as follows [4]:

Most benchmarking as per the existing literature reviews, have historically focused on the following organisational and operational areas [4]:

- Education – 5%
- Innovations and Case Studies – 7%
- Specific Applications/Case Studies – 43%
- General/Fundamentals/Models – 45%

The challenge of benchmarking within the ferromanganese production facilities is apparent noting very limited work done on innovation and learning elements within and amongst facilities and organisations. Or at least very little has been recorded to assist in the attainment of understanding how ferromanganese production is benchmarked. Only one major benchmarking study was encountered comparing the production capabilities using DC submerged arc furnace and the AC submerged electric arc furnace by Mintek in 2010. The targeted element was to be efficient with electricity use and the attainment of better economies of scale as the end result of the production process [7].

When a ferromanganese production facility looks at benchmarking, it must interrogate all aspects of the business, its products, and its processes. It is crucial for an operation to focus on anything that will impact its efficiency, performance, growth and quality.

TABLE I
BENCHMARKING TYPES

Benchmarking Type	Definition
Performance Benchmarking	It is the comparison of performance measures for the purpose of determining how good an organisation is in comparison to others
Process Benchmarking	It is the comparison of methods and processes in an effort to improve the processes in an organisation
Strategic Benchmarking	It is the comparison of an organisation's strategy with successful strategies from other organisations to help improve capability to deal with a changing external environment
Competitive Benchmarking	This is the comparison made against the "best" competition in the same market to compare performance and results.
Functional Benchmarking	It is comparisons of a particular function in an industry. The purpose of this type of benchmarking is to become the best in the function.
Internal Benchmarking	It is the comparisons of performance made between department/divisions of the same organisation solely to find and apply best practice information
Generic Benchmarking	It is the comparison of processes against best process operators regardless of industry

III. FERROMANGANESE BENCHMARKING PROCESS

There have been fluctuations in the ferromanganese market due to turbulences in the steel and iron ore commodity pricings. It then necessitates an insight into the technological processes used for ferromanganese production. The potentiality exists to examine shared applications like the furnaces, energy requirements, better materials handling techniques, mobility of labour, monitoring procedures, and research initiatives [5].

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 operation to modify the process to suit its needs and project requirements [6].

Managers of FeMn operations are continuously on the looking for techniques to enable quality improvements.

Benchmarking is one such technique that has become popular in the recent times. Though benchmarking is not new, it has now found more subscribers, and occupies a prominent place, helping quality upgradation. There are different types of benchmarking – and not all would be relevant to a metallurgical production environment.

The systematic discipline of benchmarking is focused on identifying, studying, analysing, and adapting best practices and implementing the results. To consistently get the most value from the benchmarking process, the leadership could discover the need for a significant culture change. Such change, however, unleashes benchmarking's full potential to generate large operational and strategic advantage. The benchmarking process involves comparing one's facility's performance on a set of measurable parameters of strategic importance against that of facilities' known to have achieved best performance on those indicators. Development of benchmarks is an iterative and ongoing process that is likely to involve sharing information with other ferromanganese production facilities working with them towards an agreeable paradigm of operations and/or co-

But there is always an opportunity to derive useful benchmarking inferences from other best practices outside the metallurgical industry.

Benchmarking is not just making changes and improvements for the sake of it, but it is about adding value. No FeMn production process should make changes if the changes are not going to be beneficial. When using benchmarking techniques, a furnace operation must look at how processes in the value chain are performed [8]:

1. Identifying a critical process or sub-process that needs improvement
2. Identify a productive unit that excels in the process, preferably the best.
3. Contact the excelling unit and/or organisation that you are benchmarking for a visit to study the process or activity.
4. Analysing the data.
5. Improve the critical process at your own operation.

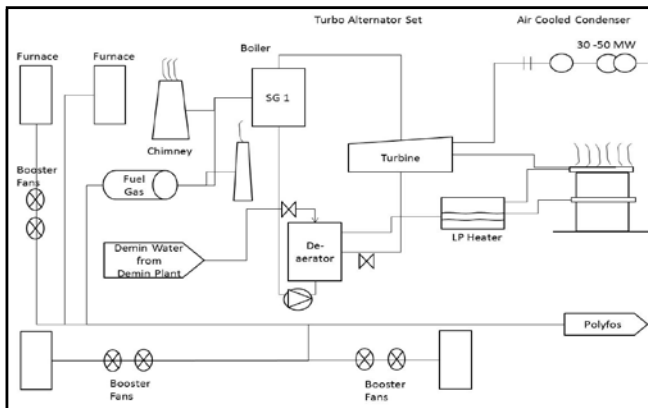


Fig. 4 Ferromanganese production process

All of these factors lead to successful benchmarking of a ferromanganese production process, or an area within a furnace operation. The main goals of producing FeMn are [2]:

- To operate on a stable and high load;
- To minimise energy consumption;
- To take care of produced metal for high Mn yield; and
- To minimise emissions of CO₂ and noxious compounds and gases.

IV. TECHNIQUES

By 2005, 75% of FeMn production was through the electric arc furnaces as compared to the blast furnace. The shift away from blast furnaces was due to expensive coke, and the lower capital investment required for electric arc furnaces. So techniques are important in determining new production processes. However, in determining the technique of ferromanganese production benchmarking, there is a need to identify the production drivers. The drivers have previously been broadly identified as thermodynamic factors, delivery factors, and leadership elements.

A technique is developed from the identification of new indicators from what is generally known [9]. In considering the thermodynamic issues, each broad

parameter like reductant availability, it can be cascaded further into sub-categories like reductant sourcing, reductant preparation and reductant blending. The same can be said with electricity usage that can be controlled when similar operators collaborate, as there are a handful of meaningful players in the industry. Rotational toll smelting can be considered in the future to bring the production costs down.

The study would culminate with a benchmarking matrix below, and it considers the development of any sub-categories and indicators for focused parameter controlling. Some of the technique elements to be factored in the production process are the following [2]:

- Minimal pre-treatment of some feedstock like reductants for better porosity;
- Charge stepped-up treatment in multiple furnaces;
- Blending of charge from different ore bodies;
- Blending of reductant of different specifications for process optimization;
- Maintaining consistent temperature levels at secondary furnaces and ladles for improved metal recovery and electricity saving;
- The use of aluminium oxide to increase manganese recovery from the slag; and
- Better preparation of the slag as a feed material.

There are five cyclic phases for implementation of benchmarking referred to as the Deming cycle ([1] and [3]):

A. PLANNING

During this phase the FeMn operation determines which process to benchmark and against what type of organisation.

B. ANALYSIS

Following data acquisition, an analysis is performed for the performance gap between the source organization and the recipient organization. An indication of best practice is then evident.

C. INTEGRATION

It involves the preparation of the recipient for implementation of actions.

D. ACTION

This is the phase where the actions are implemented within the recipient production process or operation.

E. MATURITY

This involves continuous monitoring of the process and enables continuous learning and provides input for continuous improvement within the recipient production process.

V. BENCHMARKING BENEFITS

Benchmarking benefits would be illustrated by the two most important determinants of FeMn production: availability of electricity and reductants. The operations of ferromanganese production facilities are faced with huge challenges of input costs. These costs attest to the fact that inputs like electricity provision was almost guaranteed at subsidised levels.

But such arrangements between the power generation authorities and FeMn production facilities cannot hold in the face of globalisation and competition. Governments are also competing for investments into their countries with ever increasing population sizes. Hence the competition of energy resources between communities and the FeMn production facilities has surfaced with opposition to electricity tariffs. In South Africa, ESKOM has a buy-back arrangement with smelters during the winter months to offset the availability to other social and community needs.

It can also be pointed out that the source of excellent reductants is getting fewer as years pass by. An observation made is that the mining of anthracite and coking coal is usually under difficult conditions particularly if large volumes are required. For safety considerations, mines produce volumes not necessarily meeting the entire needs of the FeMn production facilities, and the ferroalloy industry in general. Hence there is a practice of multi-sourcing from various mines throughout the world. In South Africa, smelters source the reductants from Swaziland, South Africa, Zimbabwe and Ukraine [9]. From the observations above there is a sense of urgency to fast-track innovation and learning by the FeMn facilities. It was noted that most benchmarking efforts have been on developing general models and specific applications. And it is an existing reality within the FeMn industry. Very little attention has been paid into refinement of processes and the eventual product development [3].

Benchmarking in the FeMn production facilities would assist in developing discipline, systematic processes of what would work. It would provide a sense of urgency to get a change effort off the ground. With better focus, the industry would pinpoint on developing and improving specific benchmarking indicators in respect of the process benchmarking, performance benchmarking and strategic benchmarking. There would be enhancement to strive for innovative excellence and breakthrough thinking. To illustrate breakthrough thinking, very few FeMn organisations are active participants in anthracite and coking coal mining. There is a need for a mindset shift, including considering offering better pricing for reductants. A mindset shift would lead to creating a better understanding of the ferromanganese industry by all roleplayers [10].

VI. CONCLUSION

Benchmarking could be perceived from various parameters from which the operational facility functions. These parameters are aligned to the benchmarking type i.e. process, performance and strategic benchmarking. In addition, any considerations of any parameter elements have to be aware of the context of application of the ferromanganese operations globally. The context is largely defined by striving for efficiency in production processes, improved performance, and the growth of the production facilities [3]. Hence the following benchmarking matrix can be developed for the production of ferromanganese alloys:

TABLE II
BENCHMARKING MATRIX

Process	Performance	Strategic
Customer inputs	Furnaces	Industry co-operations
Transport	Energy	Quality standards
Handling procedures	Raw materials-reductants, fluxes	Managerial leadership
Labour	Air pollution control equipment	Monitoring procedures
Delivery time	Flexibility	Cost
Reliable Mn ore supply	Raw material handling and strategies	Legal compliance

From the above benchmarking matrix, eighteen production elements were identified and observed. And the most influential ferromanganese production elements are the following:

A. Input materials

The most input elements are reductants that are mostly coke, coking coal and anthracite. These elements influence the thermodynamics and eventually contribute to the efficiency of the FeMn production process. Some organisations have developed special expertise to optimise the fixed carbon content for reduced electricity consumption. Equally important is the preparation by some FeMn operations of anthracite through further crushing to the required specification required. Most elements associated with input materials would fall under the categories of process and performance benchmarking.

B. Process thermodynamics physico-chemical elements

Ferromanganese production facilities should continuously identify new indicators of making their operations competitive. There are certain techniques that can be exploited which are fully utilised by the ferroalloy production facilities like ferronickel, ferrovanadium and ferrochrome. Very little toll smelting is undertaken in the ferromanganese production. And it can assist in the high economies of scale, as there will be more access to the manganese ore. The proposed Coega ferromanganese would operate along similar lines. Toll smelting could be used by individual ferromanganese operators either on a rotational basis on existing facilities or establish new central facilities. Elements associated with the process thermodynamics would largely fall under the category of performance benchmarking [11].

A. Co-production initiatives

It is usually not a practice in the production of FeMn for organisations to share facilities for production.

But as is customary that there are company buy-ins, investments and divestments to allow allow newer investing organisations, and cross-shareholderships. For the FeMn players, most of the cross-shareholding is done to access the manganese ore and for co-marketing purposes. The co-marketing is an inference used to observe the investors' orientation as in the mining and beneficiation of heavy sands in South Africa by mining major organisations.

The benchmarking of the ferromanganese production would require continuous benchmarking through the identification of indicators to fit into the already known production aspects. Such indicators would relate to each of the production elements, and hence the benchmarking types in the production of ferromanganese alloys

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