International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Special Issue - AMET-2018

An Overview on ITmk3 (Iron-making Technology mark three) Process

Rajas Upakare [a], Shreyas Tupe [a], Atharva Tilak [a], Aryan Thosar [a].

[a] Student , Mechanical engineering, MITCOE, Pune.

Abstract

This paper gives an insight into the ITmk3 process, a low cost, recently innovated and elegantly simple process used in the production of iron nuggets without lump ore and also avoids the need for oxide pellets or sinter and coke. This process is Direct-Reduction, is superior in energy efficiency and has low limitations about raw materials. More attention is received for this method due to rising concerns about conservation of environmental resources and their sustenance for future generations. This process has the scope to be used commercially to produce high quality iron as an important precursor to steelmaking and the same is done in some countries.

Keywords*:* Iron production, Steel manufacturing, Alternative methods, ITmk3, Rotary Hearth Furnace (RHF).

Nomenclature:- ITmk3: Iron-making Technology mark 3, BF: Blast Furnace, DRI: Direct Reduction Iron-making, EAF: Electric Arc Furnace, BOF: Basic Oxygen Furnace, HBI: Hot Briquetted Iron.

1. Introduction: Coal dependent Direct Reduction processes are the new methods used in iron and steel manufacturing. The old methods require large amounts of coke, bounteous fine ore and consume large amounts of energy which isn't sustainable in the long run considering the limited availability of natural resources in the environment. Considering these drawbacks, Kobe Steel, situated in Kobe, Japan in collaboration with MIDREX Technologies has developed a coal based Direct Reduction process which uses an easily available carbon source as a reducing agent instead of natural gas. ITmk3 is developed from FASTMET® process developed by Kobe Steel and Midrex Technologies .FASTMELT® and ITmk3 are modern processes that manufacture sponge iron (DRI) without coke.

ITmk3 is a fast iron-manufacturing process that involves reducing the finely crushed iron ore, carburizing it and separating the slag from the melt, all at significantly low temperatures compared to the previous processes. There are 3 generations of the iron manufacturing processes. ITmk3 falls in the 3rd generation. This is a completely different process from the earlier generations of iron manufacturing processes. In this method, iron ore is fed to a RHF (Rotary Hearth Furnace) in the form of pellets. Within 8-10 minutes, a series of reduction reactions occur which reduce the iron ore. This is much faster compared to the previous generation processes as they typically require 6-8 hrs.

2. ITmk3 Process:

2.1. History and development:

The prerequisites of a blast furnace manufacturing process are coking coal and sinter from iron ore. Hence, the industries that use this process must possess a production capacity greater than 10,000 tons/day to be expedient and commercially viable. This puts various constraints on the production process. Hence, flexibility is compromised. The previous generation iron-making processes that use natural gas are restricted to certain locations only. Due to this, the processes that use widely available resources are preferred. In this process, the aggregates of iron ore and coal are fed into the RHF. This aggregate is then heated by the burners present above the hearth. Melting occurs and gases are liberated which are then removed. This process was first studied at the Kobe Steel Plant in Japan. It was observed that metallic iron grows at a fast rate and gets separated from the slag at comparatively lower temperatures compared to the previous generation processes. Kobe Steel began collaborative research work involving various universities, research centers, institutes and installed a box-type furnace at the Iron & Steel Research Center in Japan that enabled experiments to be conducted on a larger scale. Plants are being constructed and developed worldwide across various countries. The first commercial plant with a capacity of 5 lakh tonnes/year was setup in Hoyt Lakes in Minnesota. Commercial plants are being setup in various countries including India, China, Kazakhstan, Ukraine, Brazil, etc.

A general timeline of events:

1996-1998: Lab testing

1999-2000: Prototype plant constructed and operated in Japan

2002-2004: A small demonstrative plant constructed and operated in USA.

2007: Construction of the first commercial plant began

3rd quarter of 2009: Authorization started.

Jan. 2010: Operation started.

Fig. 1-Rotary Hearth Furnace (RHF).

2.2. The Process

In FASTMET® process, the product obtained is directly reduced iron with a metallization degree of 85-92%. The ITmk3® process begins with the melting of the aggregate in the last zone of the hearth. The produced pig iron is of a superior quality, that is, 96-97% pure with slag as a by-product. Plants' construction is so flexible that they could be constructed in steelmaking facilities or at mining sites. ITmk3® has a major advantage which is to produce a high quality product. This allows steelmakers to obtain a high quality feedstock in EAF, BOF. Tohoku University and Tokyo Institute of Technology proposed a lucid reaction mechanism of this new process. The reaction between coal and iron ore is given as follows:

$Fe_xO_y + yCO \rightarrow xFe + yCO_2$ .... (1)

$CO_2 + C \rightarrow 2CO$ .... (2)

C(s) → C (carburized) .... (3)

Fe(s) → Fe (l) (molten) .... (4)

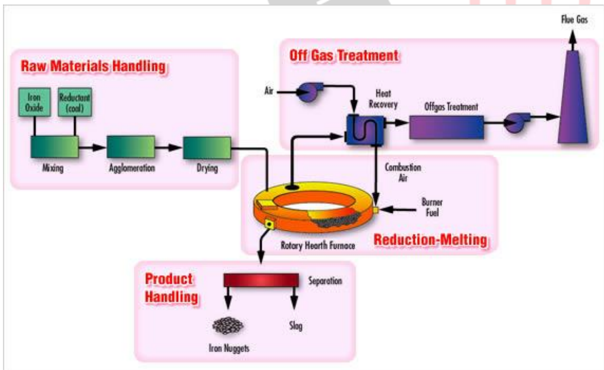

Fig.2-Flow Chart of ITmk 3process

The reactions complete in approximately 8-10 min and iron and slag are separated. The previous generation processes use bulky raw materials and hence require large amounts of time ranging from 6-8hrs. ITmk3 process gives Iron nuggets of premium purity which have similar to pig iron. It possess a metallic iron (Fe) content of 96.0 – 97.0%, Carbon (C) content of 2.0-2.5 %. Sulphur (S) levels in the nuggets are around 0.08-0.12% and the density of the obtained nuggets varies from 6.5-7.0 gm/CC. Pig iron nuggets manufactured from BF process have higher melting point than nuggets manufactured from ITmk3 process and also gives good meltability. Iron nuggets are easy to transport and handle. They do not re-oxidize. Another advantage is that they can be continuously fed into the EAF. The time wise analysis can be found out as such: During the first few minutes of the process, the briquettes did not show any significant change in appearance. After some time the metallic iron and slag start to melt. Later, the entire aggregate starts to melt faster, with metallic iron being separated from the slag. After 9-10 minutes, they had separated completely.

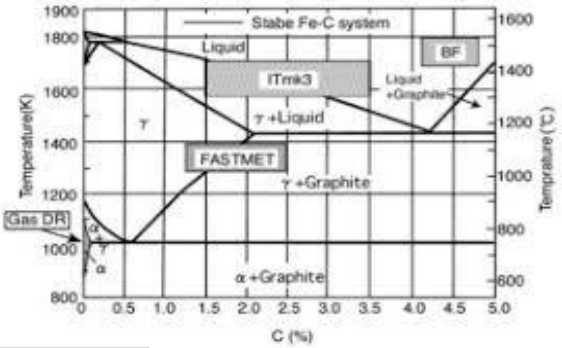

Fig.3-Iron Carbon diagram for pig iron by

ITmk3 process.

Table 1-Chemical Analysis

Elements	Content (%)
Metallic Iron	97.2
Phosphorus	0.01-0.025
Carbon	2.0-2.4
Sulphur	0.07-0.12

The process can be simply summarized as follows:-

1. Fine iron ore and pulverized coal are made into pellets.

2. These pellets are fed into a Rotary Hearth Furnace (RHF), heated at 1350-1450 ^{0}C, for about 8-10 minutes, reduced and melted. The slag is then separated.

3. Iron nuggets are obtained by cooling the molten iron in the furnace itself.

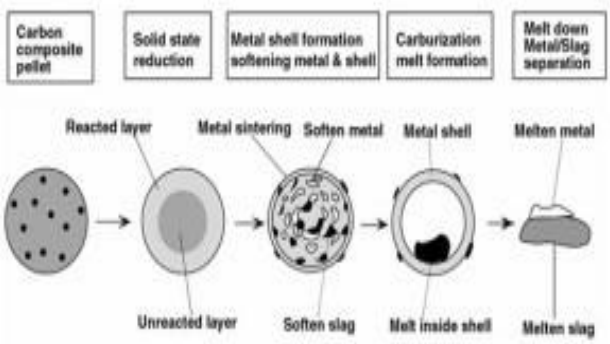

Fig.4-Iron Nuggets manufactured through ITmk3

Table 2- Resources required for ITmk 3

Fine Iron ore	1350-1360kg
Non-coking coal	450-460kg
Air	80-85 m^3
Electric Power	200 kWh
Distilled Water	2 m^3
Fuel Gas	4600 MJ
Nitrogen gas	12.5 m^3

2.3. Merits of the new ITmk3 process:

1. It is a simple process and has commercial utility for producing premium quality pig iron nuggets.

2. One-step processing can be achieved in 1/60th of the time compared with conventional blast furnaces.

3. Directly reduces the iron ore with non-coking coals. Non coking coal is mainly used in power generation and has high ash content.

4. This process consumes less energy and is more efficient than the previous generation processes.

5. Allows processing at lower temperatures and burns less costly fuels, including steaming coal.

6. Energy usage is improved along with processing efficiency, which reduces emissions by up to 20% compared with conventional blast furnaces.

7. Low grade iron ore can be used in this process and high quality pig iron with good meltability for steelmaking operations is obtained.

8. Small capital investment is required and the process facilitates production adjustment.

9. The iron nuggets are free from slag, tramp elements and also are easy to transport.

10. The equipment used in this new process have proven reliability and are easy to operate.

3. Conclusions and Future Scope:-

1. The commercialization of this process has just started and is expected to expand in the coming years.

2. Some plants are already operational in parts of USA and Japan. Pilot plants are being setup in developing countries like China.

3. This process is used in those industries where high grade iron nuggets are required.

4. The iron nuggets produced by this process have good meltability and hence, increase production speed.

5. Due to its comparatively environment friendly nature, it is gaining widespread appeal around the world.

4. References:-

1. Larry Lehtinen : Mesabi Nugget Research Project, United States Department of Energy (2005).

2. S. Meissner: The 11th Japan-Germany Seminar on Fundamentals of Iron and Steelmaking, Reduction and Meltdown of Pellets in the ITmk3 Process, (2002), p. 6.

3. Rahul Davis, Mohamed Alazhari, Analysis and Optimization of Surface Roughness in Dry Turning Operation of Mild Steel, International Journal of Industrial Engineering Research and Development (IJIERD), 3(2), 2012, pp. 01–09.

4. Ko-ichiro Ohno : "Steel Research," 74 (2003), pp. 5-8

5. Dr. B.V.R. Ravi Kumar, A Review on Importance of Micro alloying in Steel. International Journal of Industrial Engineering Research and Development (IJIERD), 5(2), 2014, pp. 187–193 .

6. KOBELCO ITmk3, Kobe Steel, Kobe, Japan.

7. Parametric Analysis of Erosion Rate And Thermal Characteristics Of In-Bed Tubes In Atmospheric Fluidized Bed Combustion Boiler, Amit Vishnu Jomde, Satishchandra Joshi, Suhas Deshmukh, Virendra Bhojwani, Pralhad Tipole

8. S. Kikuchi, S. Ito, I. Kobayashi, O. Tsuge and K. Tokuda: *KOBELCO Tech. Rev.*, (2010), No. 29, 77.