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Editorial Desk

D. A. Chandekar
Editor

Dear Readers,

The steel demand in the country seems to be increasing steadily thanks to the user sectors like infra, construction and auto. The first sign of recovery was visible in September when auto sales showed sizable improvement. Many thought it was accumulated demand as there was almost nil sale during the first few months of lockdown. When the positive trend continued in subsequent months, still it was stamped as festive spike. Now that this upward trend is still continuing, experts are believing it to be a sustainable growth. Lets hope this continues and 2021 be a better year for iron & steel sector in the country.

As mentioned in my last month's column, after the pandemic, there is a greater need for the industry to be competitive in the global marketplace and for that it must adopt smart manufacturing processes and techniques. Many companies in the manufacturing sector have started looking at Industry 4.0 solutions for increasing the productivity, efficiency and competitiveness of the enterprise. The deadly pandemic has also taught us to care more for the mother earth and thus the iron & steel sector needs to develop environment friendly production and processing technologies creating minimum waste and controlling emission of harmful gases. One such process being developed uses hydrogen as reducing agent instead of coking coal. It is supposed to reduce the carbon footprint during steel production. The problem in developing such green processes is that they are costlier than the prevailing process. It is a big challenge to make them commercially viable so that the industry adopts them for regular use.

The covid period has not only changed the working and thinking of corporations but it has also changed the mindset and the priorities of the society. My gut feeling is that this will have a gradual but definite effect on steel demand profile. Let us remain alert and keep watching how the situation unfolds in coming months !

Write your comments :
https://steelworldblog.wordpress.com/

Low-carbon footprint iron making process with Microwaves : A dream that will become reality

Abstract:

Is zero-emission steelmaking a utopia?

Iron & steel manufacturing process contributes about 8% of Green-house gas emissions, which is one of the highest. At present, international efforts have been initiated to modify the present process to achieve carbon neutrality by 2050 and eventually zero-emission steelmaking. Pradeep Metals Ltd., a leader in precision closed-die ferrous forging, took this challenge to invest in its in-house R&D centre IMRC for developing a novel pig iron manufacturing process using microwave energy. The first phase of this project was completed recently with a successful demonstration of the process. This article describes the new iron making process, its advantages, and future plans of scaling-up the process.

Preamble:

Blast furnace suppliesmore than 90% pig-iron to the steel industry. This process demands lumpy iron ore, coke and coal/natural gas, as fuel and reductant. Scarce and expensive requirement of coke (350kg/tHM –Tons of Hot Metal) is the biggest disadvantage. Coke making is not an environment friendly process. The alternative is the Corex process which produces liquid iron through reduction-smelting using coal and Oxygen. The main disadvantage of this process is high fuel rate and complicated controls.

Background - PML &IMRC

Pradeep Metals Limited (PML), a leader in precision closed-die ferrous forging company, established a R&D center"Industrial Microwave Research Center"(IMRC)in 2006 for developing environmentally friendly, energy efficient microwave assisted processes. IMRC is recognized as an in-house R&D Center by DSIR, Govt. of India. Few technologies developed and patented by IMRC are listed in Table1. PML-IMRC received the 'Best Patent Portfolio' award from Confederation of Indian Industry (CII) during its 6th International Conference on IPR held on 18th December 2020.

Table1: Technologies developed/patented by IMRC

Patent title	Filing date/Grants
Batch or Continuous Process for Pretreatment of Heavy Petro Bottom Stocks	Granted (N0. 277603)
Conversion of Iron Ore to Sponge Iron	Granted (N0. 309420)
Coal Pre-treatment	Filed 2012
Rapid Processing of Grinding Wheels	Granted in US, Japan, China & India
Continuous baking of friction materials	Filed 2013
Coal liquefaction yield enhancement	Filed 2013
Processing of Goethite Ore Using Microwave	Filed 2015
Microwave Composite Heating Furnace	PCT filed March 2017 in India,
(jointly with Chubu University, Japan)	South Africa, Canada, China, Brazil. Granted in Ukraine, Russia, Australia & Japan

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Paradigm shift:

Blast furnace requiresiron ore with > 60%Feandlump size between 12.5-35 mm. Smaller size ores are either used for sponge iron making or rejected. Similarly, low grade ore (<60%Fe) requires different beneficiation processes depending on the gangue. Several techniques like washing, jigging, magnetic separation, advanced gravity separation and flotation are being employed to enhance the quality of the iron ore.This generates unwanted rejects around the plant and mines which creates environmental pollution and destroys fertile land. This is a serious problem faced by Goa iron ore miners. This was highlighted by the late Chief Minister of Goa, Mr. Manohar Parrikar during his discussions with IMRC and prompted our researchers to work towards value addition to this waste material.

IMRC initiated working with different Indian iron ores including Goa and Orissa to study their behaviour with microwaves. During initial stage of the research, it was noticed that iron ore (hematite) interacts rapidly with microwaves (Refer Fig.1).

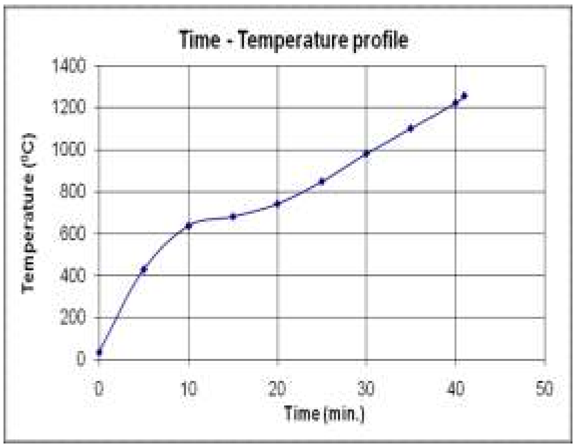

Fig. 1: Time temperature profile of hematite under microwaves

Direct reduction of iron ore with microwaves:

Iron ore reduction activity was then pursued, and a new microwave assisted process for sponge iron making without carbon was developed. A patent entitled "Microwave assisted reduction of iron ore fines to manufacture sponge iron" was granted in India on 19th March 2019 (No. 309420). In this process, iron ore was converted to sponge iron at around 1100°C using microwaves while maintaining reducing atmosphere with 8% H_2 + 92% N_2.

This research was extended, anda project entitled 'Microwave Assisted Iron Making Process' was undertaken by IMRC to develop a new environment friendly microwave assisted technology for making pig iron by utilizing powdery iron ore and coal, which is generally not used in blast furnaces. The USP is zero use of coke and only stoichiometric quantity of carbon for reduction,based on our calculations. For appropriate stoichiometric requirement, our calculation shows that a high degree of direct reduction, >80% below300kg/htm (Hot Ton of Metal) would be possible which is a unique feature of this process. This reduces the Green-house gas emission by almost 50%, making the new process eco-friendly.

IMRC conducted several experiments using different iron ores. Two representative results are summarized below (Fig.2):

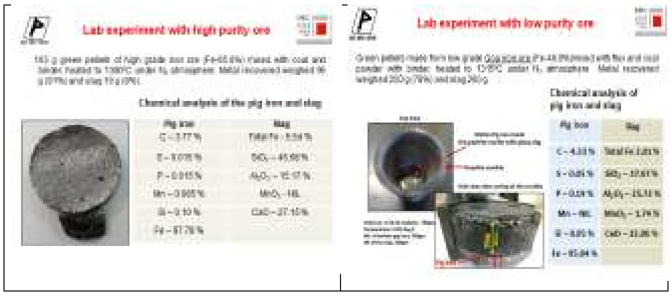

Fig. 2:Results from laboratory scale using high and low purity iron ore

IMRC collaborated with Dr. Motoyasu Sato of Chubu University, Japan for designing a prototype high powered microwave assisted plant and conducting scale-up trials .PML received a partial grant from the Ministry of Steel through their Steel Development Fund (SDF) for establishing a prototype plant. The prototype plant in knockdown condition was received at IMRC which wasinstalled within a short duration of 15 days (Fig.3).

Fig. 3: Microwave assisted prototype plant installed at PML

Initially no-load testing of all microwave systems was completed. The first integrated experiment could attain only 1200^{0}C. Prominent problems noted were: a) Rapid increase in the temperature of exhaust fan body, b) Oxidizing atmosphere in the furnace (O_2 14-18%), and c) Insufficient microwave energy reaching the reduction zone (only 10-20%).

IMRC team addressed the issues by incorporating different design modifications and confirming the same after conducting requisite trials. Several minor concurrent problems were also addressed meticulously with hard work. The initial plant design was eventually altered to a large extent to achieve the desired results. To increase the microwave efficiency and power reaching to the reduction zone, the microwave antennas (waveguides) were redesigned and verified using sophisticated simulation models available at SAMEER (Society for Applied Microwave Electronics Engineering & Research,)IIT, Mumbai. The kiln furniture was the next challenge. Blast furnaces refractories were found unsuitable under microwaves due to their unwanted interactions. The requirement was a ceramic material which could withstand high heating rates& high temperatures, transparent to micro waves and would not interact with molten iron & slag. IMRC researchers could overcome these hurdles and a suitable coating was developed. The final process parameters were evolved through several systematic experiments and a standardized operating procedure (SOP) for conducting microwave assisted trial was evolved.

The largest continuous trial was conducted at 1420-1450^{0}C where about 15 kg raw-mix was fedand 8.15 kg product was obtained. The reaction was monitored through the top observation window. (Fig.4). Few trials were conducted with continuous tapping of hot metal & slag through tap hole (Fig.5).

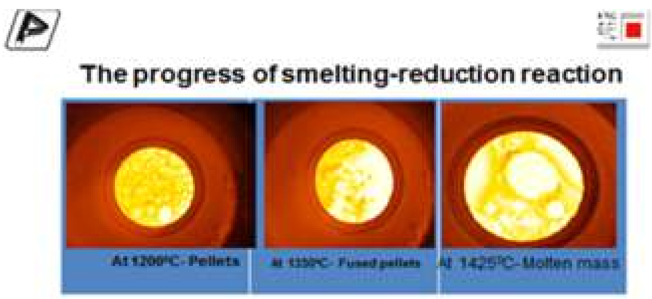

Fig.4: The progress of smelting-reduction at 1200,1350 & 1425^{0}C

Metal and slag obtained in each trial wasanalysed for its chemical composition. The ranges of the constituents in number of experiments aresummarized below in table2 below:

Figure5: Tapping of hot molten material (metal + slag)

Table 2:Chemical composition of (1) metal and (2) slag

1) Metal analysis

Metal Constituents	C	S	P	Mn	Si
	1.63-2.16 %	0.016-0.12%	0.012-0.08%	0.025-0.088 %	0.08-0.18%

2) Slag analysis

	SiO_2	CaO	Al_2O_3	MgO	Fe_2O_3	MnO	TiO_2	S	P
Slag Constituents	40.5-44.1 %	24.6 - 30.2%	11.5 - 18.9%	4.8 - 8.02%	2.5 - 3.01%		0.5 – 1.3%	0.15 - 0.17%	0.06 - 0.08%

Conclusions:

Microwave assisted process for pig iron making is a totally new process with no parallel references.

PML has successfully demonstrated a process for making purer pig iron (bordering on steel) using microwaves.

The process is green and uses only fine coal (no coke) and fine ore (without agglomeration). It will lead to not only significant reduction in Green-house gas emissions, but will also eliminate the harmful emissions generated during the processes of sintering and coke making. Thus the process is environmentally very favorable.

The reaction kinetics of the process is very fast, which is conducive for attainment of high production rates. The process consumes a low coal rate below 300 kg/tHM as against about 550-600 kg (coke + coal)/tHM in a conventional Blast furnace. Present limiting factor of this process is high power consumption, which is about 15-20 KWh/kgHM. This requires a redesigning of the total system and optimization to attain low power at higher scale of operations.

Concluding thoughts:

Iron & Steel sector is responsible for one-third of all industrial Green-house gas emissions. It consumes almost 30% of all coal produced. As per World Steel Association, every ton of steel produced in 2018 emitted 1.85 tons of carbon dioxide, equating to about 8 percent of global carbon dioxide emissions. To reduce its carbon footprint from both environmental and economic perspectives, it is essential to decarbonise the steel industry and adopt low-carbon, primary steel production processes. The high developmental cost and capital needed may increase the steel price by almost 50%.Hence, the Industry and the government focus should shift to promoting novel, low carbon technologies, by subsidizing the capital investment and on consumption of renewable electric energy and other alternate non-conventional fuels. New policies can be pursued to bring about reduction of green-house gas emissions either by offering incentives to low-carbon technologies or to penalize carbon intensive technologies. To reduce carbon footprint, international steel industry is making efforts to use new low carbon required processes and has decided to adopt it by 2050. We believe that Indian Scientists should not miss the bus but should come out as a prominent technology supplier of green processes.

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