THE PRODUCTION OF SPONGE IRON UTILIZING THE MIDLAND-ROSS PROCESS AT HAMBURGER STAHLWERKE GMBH

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Summary

The Midland Ross direct reduction plant at Hamburger Stahlwerke is the third of its kind producing sponge iron since 1971. Economical and technological aspects of this new concept of a steel mill are studied. Concerning the direct reduction process particulars are given about plant installations, gas re-forming, input materials, final product as well as first operational results.

Each investment is preceded by a period of planning, in which the market situation, technology, economics, as well as the forecast developments will be thoroughly analysed.

The planning of a new steel plant involves the following considerations

a) which products are to be produced and how is their market situation?

b) raw materials, energy and manpower, can they easily be provided and are they available in sufficient quantities?

c) which are the most efficient processes as to the kind and quantity of desired products?

Availability and expenses for raw materials and energy are playing a very decisive part in these considerations, because all further process steps will be affected hereby.

Steel works of conventional design still are depending on blastfurnace coke as main energy sources although no effort was spared to lower the amount of coke since expenses for coke was rising more and more.

Price developments not only, but also availability and possibilities of handling of the different energy sources leading to a displacement in the portion of primary energy forms which up to now are not concluded (Fig. 1).

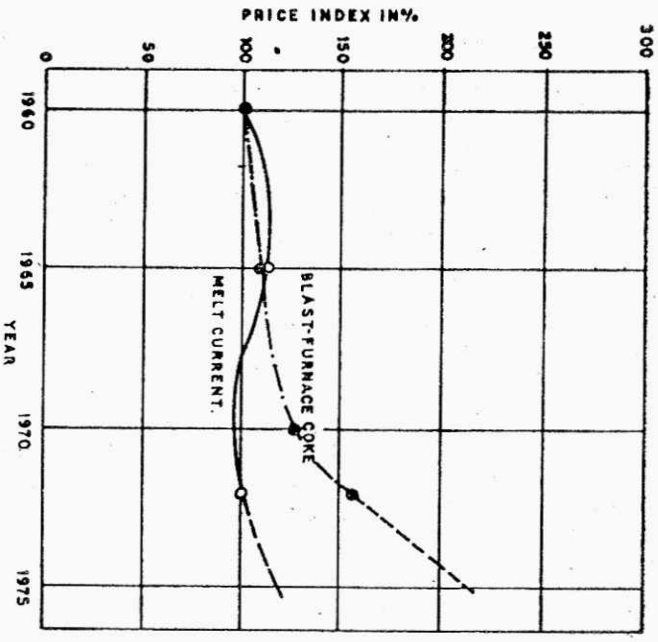


Fig. 1 Price development of the energy sources blast-furnace coke and melt current.

It can be counted for that even in future the rise in prices for blastfurnace coke will be stronger than those for other forms of energy, by which the expenses for energy in the blast-furnace process will be extremely influenced (Fig. 2).

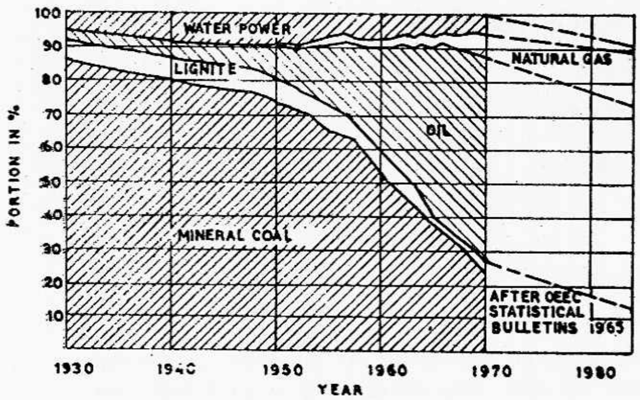
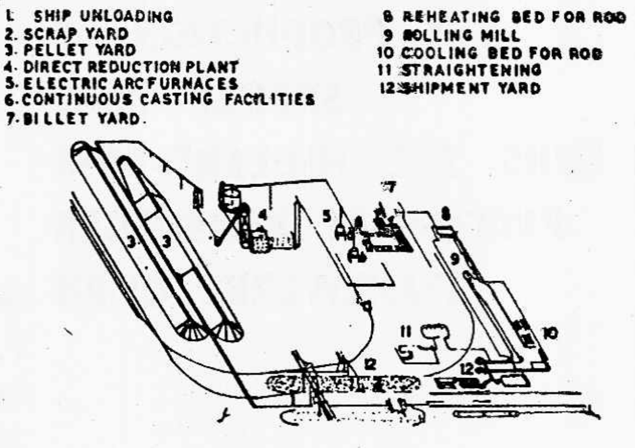


Fig 2 Proportional consumption of primary energy sources in OEEC countries.

Direct reduction of iron in combination with electric steel making therefore represents a better solution in comparison to the conventional process blastfurnace/basic oxygen shop concerning at least the expenses for energy. In many cases where blastfurnace coke is not available, direct reduction will be the only possibility for the production of iron since either solid, fluid or gaseous reduction media can be used.

Opposing economical and technological aspects show that by realizing an economical production of metalized iron ore a new type of integrated steel works can be originated. It represents a true alternative to steel works of conventional design. The process technique direct reduction/ electric steel making therefore will gain of importance more and more and will play its part besides blastfurnace/basic oxygen process.

Exemplified by Hamburger Stahlwerke, the operations of the direct reduction process developed by Midland Ross Co. USA, shall be illustrated. The direct reduction plant of Hamburg is the third plant of its kind after two were going into operations in the United States at an earlier time already. The fourth direct reduction plant is going into operations in Canada within the next weeks.



PRODUCTION FLOW SHEET OF HAMBURGER STAHIWERKE

Figure 4 shows the layout of the plant and the material flow sheet. Within the continuous-material flow, starting with unloading the ore carriers up to the point where the finished products are to be shipped, only two interruptions exist, where the material has to be transferred by crane. In all other cases the material is transported by conveyor belts or within the process line itself. Utilizing the direct reduction/electric furnace steelmaking technology short transport distances from raw material to finished product can be achieved in largely mechanized and automated material handling lines. Thus, this design represents a further step in the direction to the goal to integrate different process steps into a continuous production sequence.

The reduction plant for itself basically consists of the gas reforming system which provides for the generation of the reduction gas, and of the shaft furnace. as well as several other systems serving for gas washing, cooling and gas mixing. It also includes inplant transport devices. The entire handling of ore, gas, water and metalized pellets is supervised and controlled centrally.

The shaft furnace with its inside diameter of approximately 4.80 m encloses a volume in the order of 300 m^3, whereof only one half is required for the actual reduction zone; the remaining area consists of the conically tapered cooling zone and is reserved to several in furnace assemblies (Fig. 5).

The furnace is charged by means of a skip hoist, controlled by the burden level indicator at the burden hopper.

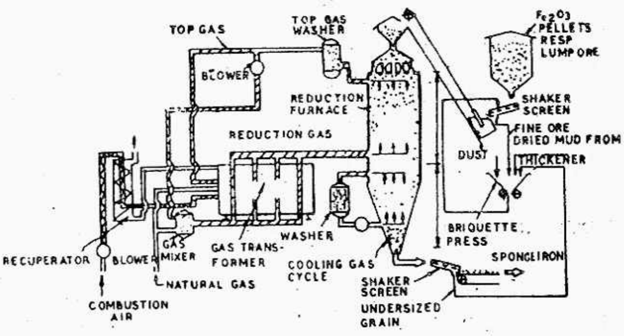


Fig. 5 Process sheet of the direct reduction according to Midland-Ross operations.

Beneath said burden hopper there is a distributor assembly by which the ore flows into the furnace through a major number of feed pipes. A completely uniform charging is obtained by this charging system, since contrary to the effect of furnace top bells the formation of charging cones within the burden and thus grain separation are prevented. For the counterflow principle in the shaft furnace this is of particular importance in order to achieve an optimized chemical and thermal utilization of the reduction gas. The charging column of the ore as well as a dynamically operated inert gas seal equilibrated with the furnace gas pressure avoid the escape of top gas at the burden hopper. The shaft furnace is subdivided into two zones of different gas circuits. The actual reduction zone in which the ore is heated up to the required temperature and at the same time reduced, is located in the upper part between reduction gas entry and furnace top. Through a closed circuit gas line, the reduction gas enters into the reduction shaft by several inlets and ascends uniformly distributed through the charging column. By means of the hot gas the pellets get heated up and metalized within the range of 6.5 hours while passing through the furnace. Beneath this zone there is the cooling zone in which the metalized pellets are cooled down to temperatures of approximately 35°C by means of a special cooling gas. Between reduction and cooling zone there are devices to inhibit the cooling gas from affecting the reduction in the upper part of the shaft.

Additionally, these devices bring about a forced transport of the material within the furnace and thus give the opportunity of controlling the furnace throughout. Discharge of cooled metalized pellets from the furnace is done continuously by a wiper bar mechanism which throws the material onto a conveyor belt. At this point a dynamically operated inert gas seal has been installed as well to avoid any escape of cooling gas. On different conveyor systems, the metalized pellets pass directly to a storage silo or to the melt shop for direct use.

A simplified scheme of the Midrex reduction process used in Hamburg is represented by Figure 5. Iron ore reduction is performed in a shaft furnace by the hydrogen and carbon monoxide components of the reducing gas. The iron ore pellets, continuously fed into the shaft, are exposed in counterflow to the reducing gas mixture, whereby they are reduced to metallic iron. The metallized product descends through a cooling zone in the lower section of the furnace to the bottom, where it is discharged continuously onto a rubber conveyor belt.

The reducing gas is produced in a gas reformer by continuous catalytic reforming of natural gas with a part of the recirculated top gas which contains a certain amount of CO_2 and H_2O. In essence, H_2 and CO remove oxygen from the iron oxides and this oxygen reacts within the reformer with CH_4 to form more CO and H_2. No steam, air, oxygen or other external oxidants are required and therefore high fuel efficiency is attained.

Since cracking of the methane with the CO_2 and H_2O contained in the top gas is an endothermic process, and additionally the reduction gas is used to heat up the burden column in the shaft, an undergrate firing of the gas transformer is required. This heating is achieved by the combustion of natural gas in combination with preheated air and the remaining part of the top gas. The hot waste gas generated is used recuperatively to preheat the combustion air. The advantage offered by this gas cracking system is that by an almost uniform range of temperature as well as by separating the reaction and combustion chambers, a continuous and thereby optimized operation can be achieved.

With this sophisticated system of almost complete recirculation of the process gases and efficient utilization of waste heat, low energy consumption can be achieved. Running at full capacity, the energy consumption per ton of sponge iron amounts to 13.6 Mio BTU gross calorific value or 12.1 Mio BTU net calorific value.

	NATURAL GAS %	REDUCT GAS %	COOLING GAS %	TOP GAS %
CO_2	0.8	0.5-3	6-10	16-22
O_2			0.5-1	
CO	–	24-36	16-24	25-16
H_2	–	60-40	32-23	38-47
CH_4	81.9	3-6	3-6	3-6
N_2	14.0	12-15	43-36	22-9
C_2H_6	3.3	—	—	—

Fig. 6 Approximate composition of gases used in the Midrex direct reduction process.

The composition of the gas used in the different circuits is represented in Fig. 6. Regulating the amount of oxygen compounds by means of a very sensitive control and mixing system, the composition of the reduction gas is optimized.

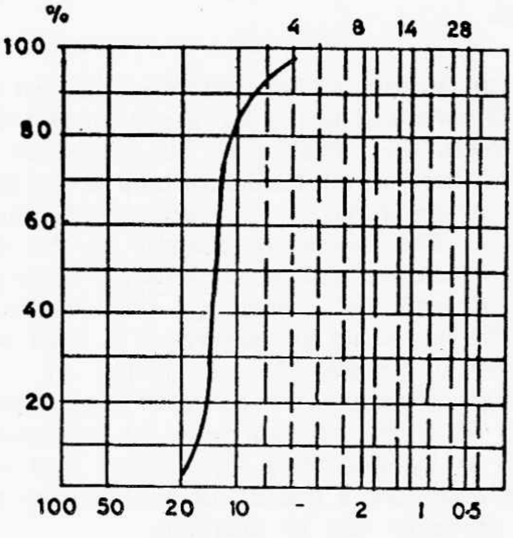
Fig. 6 shows the composition of the gas used in the cooling circuit as well. This gas used as a coolant for the hot sponge iron on one hand additionally serves as a protective against reoxidation of the metalized iron ore. Cooling of the circuit gas also is provided by means of a gas washer.

Water requirements of the plant are met by two circuits with corresponding recooling systems. The clean water system essentially serves to the cooling of machinery and equipment, whereas the dirty water system provides for cooling and cleaning of the gas circuits. The dirty water is freed from its mud by pumping it into a 17 m diameter thickener. Both water circuits have a throughput of roughly 12 m^3/min.

Raw material and finished product

Until today, the Hamburg reduction plant exclusively has processed Swedish Malmberget pellets which can be supplied to Hamburg at an exceptionally favourable freight rate. Due to their analysis and their chemical and physical properties these pellets produced in the shaft furnace from a magnetite concentrate are qualified especially for direct reduction or as metalized iron ore for further processing in the electric arc furnace. Of some importance concerning the pellets are the following values: low content of gangue components, unimportant values of trace elements, favourable low swelling, no decrepitation, as well as a good compression strength. The data of Malmberget pellets are shown in Fig. 7.

The chemical composition of the metalized iron ore when using Malmberget pellets appears relatively consistent as indicated by the values shown in Fig. 8.



Fe_3O_4	1.24 %	Fe	67.78 %
Fe_2O_3	95.53 %	Mn	0.03 %
FeO	—	P	0.022 %
MnO	0.04 %		
CaO	0.18 %		
MgO	0.32 %		
Al_2O_3	0.48 %		
SiO_2	1.55 %		
TiO_2	0.28 %		
V_2O_5	0.19 %		
P_2O_5	0.05 %		
S	0.002 %		
CO_2	0.16 %		
Na_2O	0.11 %		
K_2O	0.05 %		
CuO	0.01 %		
TOTAL	100.29 %		

DENSITY : 5.1 g/cm^2
BULK DENSITY : 2.1-2.2 g/cm^3
MOISTURE : 1.5 %
TUMBLER TEST : T: 93 % + 6.3 mm
COMPRESSION STRENGTH : 250 kg
REDUCIBILITY AT 1000°C R_{40} = 0.55/MIN

Fig. 7 Characteristics of Malmberget-Pellets

Fe tot	92	96%
Fe met	appr	91%
DEGREE OF METALIZATION	appr	95%
P		0.025%
S		0.010%
SiO_2		2.00 %
Al_2O_3		0.70 %
MgO		0.50 %
CaO		0.25 %

Fig. 8 Average analysis of metalized iron ore charging Malmberget pellets.

From the representation in Fig. 9 the deviations are evident in respect to Fe_{tot} and the degree of metalization which occured during an interval of six weeks. The carbon content which has to be considered particularly in electric steelmaking, may be varied within certain limits by means of a controlled process.

Generally the content may be adjusted to between 0.8 and 2.0% of carbon accepting, however certain deviations. Fig. 10 shows the scattering of carbon contents as resulting from various shaft furnace campaigns. To steel workers engaged in metalized pellet processing it is of advantage to obtain the carbon required for certain steel grades already contained in the charged materials. It has been proved in practice that the carbon content of the first analysis of the heat can be maintained rather exactly when feeding metalized pellets with carbon contents within certain ranges of deviation. An increase of the carbos content in metalized iron ore can of course be effected by the gas phase only at the expense of an additional devaluation of the reduction gas. Thus for an increase of the carbon content by 0.1% approximately 12,000 kcal per ton of metalized iron ore have to be applied. While at present this figure may appear to be rather high such amount is indeed comparable to that of other carbonizing materials normally used in melt shops.

Total production of the direct reduction plant is used in the electric steel shop of Hamburger Stahlwerke up to now. A separate paper will be held concerning the experience of processing sponge iron into steel.

Natural gas is used as energy source today in all operating Midrex direct reduction plants. Further developments concerning energy requirements mainly aim at the utilization of this process to countries where no natural gas is available.

Principally it is possible to use other forms of energy to generate the reduction gas. The most simple way to substitute the lack of natural gas is the usage of liquified natural gas, which may be brought to the area by tankers. Second, Naphta may be used, which is a by-product of

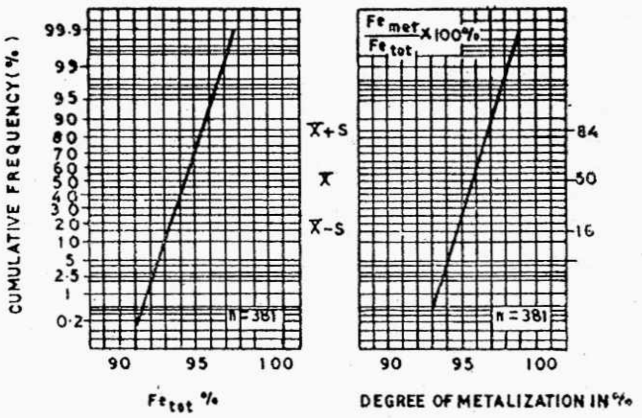


Fig. 9 Scattergram of Fe-contents and degree of metalization in metalized iron ore over 6 weeks of operation.

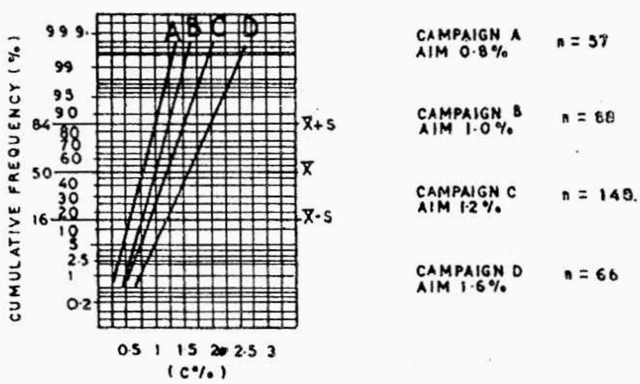


Fig. 10 Scattergram of C-contents in metalized iron ore at different campaigns

the distillation process in oil refineries. Plants which are converting Naphta into rich-gas according to the Recarto process are approved in large scale already. The generated gas may be used directly in the Midland-Ross process instead of natural gas. Furthermore particular consideration has to be given to the development of high temperature reactors which as a source of energy for direct reduction as well as steel production surely is of great importance.

Other advantages known already and likely to be effective in the future are so important that this new steelmaking concept is being taken into considerations for further investments of steelworks which on account of their size have exclusively been reserved so far to classic steelmaking operations.

Discussion

Prof. S. L. Malhotra, (Banaras Hindu University, Varanasi). I would like to know about the following points: (1) The discharging system for the product and the considerations that led to the design of the discharging system (2) The thermal profile in the furnace and the maximum temperature in the furnace.

Dr. W. Maschlanka (Author) (1) The wiper bar system of the reduction furnace consists of a horizontally assembled chute-shaped lid being moved to and fro by means of an eccentric shaft. By the movement of the lid, a certain respective quantity of sponge iron is removed from the furnace and discharged onto a rubber conveyor. On top of the wiper bar, there is an inlet for the seal gas preventing the cooling gas from leaving the system. This construction has been chosen since it is a relatively simple and safe device. (2) The temperature in the reduction zone of the furnace is nearly constant falling off sharply at a distance of approximately 1 m only beneath the feeding and surface area. The maximum temperature within the furnace depends mainly on the sticking point of the ore. Consequently, the temperature shall be chosen in a way to remain shortly beneath this point.

Mr. P. V. T. Rao (Tata Iron & Steel Co. Ltd., Jamshedpur). Stock descent may not be uniform over the entire cross-section of the furnace shaft. This may result in the difference of time of contact between the ore particles and gas passage, causing non-uniformity in the product being formed. How this difficulty is overcome? I mean that the material descending from the centre moves faster than the material near the wall of the shaft. This results in the difference of time of contact between the gas and material moving through different parts of the shaft. This finally may result in difference of reduction. How this difficulty is overcome?

Dr. W. Maschlanka (Author). Descending of the burden column within the Midrex reduction furnace is controlled by transport devices assembled in various plains beneath the level of the reduction gas inlet. In this way, the material is prevented from descending irregularly through the furnace. The sponge iron produced thus will be highly homogeneous on its anlaysis.