PRODUCTION OF PIG IRON WITH THE USE OF COKE IRON

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The investigations on the production of coke iron and its application for iron smelting were started during the Korean War.

At first, by making use of the experience accumulated during the investigation of the possibility of the production of pig iron with the use of anthracite, and by utilizing the method of the manufacture of ore briquettes, we carried out some elementary experiments and thermodynamic calculations which showed that if the blast furnace is filled with briquettes made of a mixture of iron ore concentrate and coal then the iron oxide is rapidly reduced to a metallic state, provided that the strength of the briquette is retained. Therefore, one can obtain pig iron from these briquettes in low shaft furnaces (during the war we were not in a position to build blast furnaces of a normal height but there was an urgent demand for pig iron).

The workers and technical personnel of the Kim Chak Iron and Steel Factory undertook to continue the investigation of the production of pig iron in low shaft furnaces. In September, 1951, we started to make briquettes from a mixture of Musan iron ore concentrate and various coals. These briquettes were resistant to cold and high temperature and stood up well to the pressure in low shaft furnaces. They were called "reducing iron-ore briquettes."

Under war conditions, no experimental apparatus was available for testing briquettes at a high temperature and, therefore, we carried out industrial tests directly in a small blast furnace during a trial smelting operation. To strengthen the briquette we subjected it to thermal treatment under pressure. The strongest briquettes were obtained from a mixture of iron ore concentrate and coking coal. This is explained by the fact that, in the course of the thermal treatment, the coal was converted into coke, and oxides of iron were reduced to metallic iron.

We called such briquettes "iron-containing coke," and later on we gave it the name of coke iron.

As a result of the laboratory preparation of coke iron the following facts were ascertained:

1. During the coking most of the Musan iron ore concentrate is reduced to metallic iron, the extent of the reduction being dependent on the conditions of coking. At the same time the grains of the reduced metallic iron adhere strongly to the neighboring grains of iron or carbon. Therefore, the mechanical strength of the coke iron produced depends on the content of iron ore concentrate in the charge prepared for coking. Up to a certain limit of the concentrate content the mechanical strength increases and then gradually decreases (Fig.).

2. When coke iron is used there is no need for high blast furnaces since the iron contained in the coke iron is already partly reduced.

3. Coke-iron production makes it possible to utilize pulverulent iron ores.

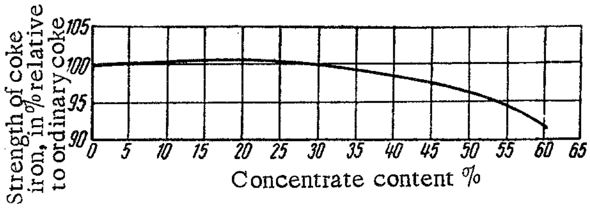

Figure. The dependence of the mechanical strength of coke iron on the content of the iron ore concentrate in the charge.

4. In the process of coking, the ore is deoxidized by methane, hydrogen and other reducing gases which are produced during the coking. The heat necessary for the deoxidation is supplied by the combustion of the coke-oven or blast-furnace gas used for heating the batteries. Therefore, less coke is used in the production of pig iron.

5. A reduction in the consumption of coke per ton of pig iron results in a reduction of blast consumption and an increase in the efficiency of the blast furnace. On the other hand, since the height of the furnace can be reduced, it is possible to improve the ratio of the working volume to the daily output of the furnace still more.

6. Under ideal conditions, when coke iron is used in the blast furnace for the production of pig iron, no other iron ores need be added, but then the content of the iron ore concentrate in the coking charge should be very high. The coke iron contains excess carbon and, therefore, during the smelting of pig iron from coke iron it is necessary to charge some additional ore and flux into the blast furnace.

After the All-Korea Conference of Scientific Workers (April, 1952) the problem of the production of pig iron from coke iron, which had been investigated for more than ten months, was discussed very extensively. Specialists in this field expressed appreciation of the work done so far.

Experimental semicommercial blast furnaces for the production of coke iron and for the smelting of pig iron were built in a region relatively safe from enemy bombardment. Large-scale tests confirmed the results of laboratory experiments and made it possible to obtain data on the process of smelting pig iron from coke iron.

The production of coke iron with an addition of iron ore concentrate to the coking charge was started in 1956, (in a coke-oven battery of 57 chambers); 14,585 tons of coke iron were produced in that period. The results of this operation showed that if the necessary operating conditions are maintained it is possible to obtain good-quality coke iron charge containing up to 60% concentrate. The silica-refractory walls of the coking chambers are not affected by the slag. The coke iron can be pushed out with the ordinary coke pusher. The composition of the charge and the properties of the coke iron produced are given in Table 1.

TABLE 1

The Composition of the Charge and the Properties of Coke Iron

Components	Composition of the charge, %		
	charge 1	charge 2	charge 3
Sankhav coal	40	35	30
Keren coal.	50	40	35
Musan concentrate.	10	20	30
Anthracite	—	5	5
Properties of coke iron			
Ash	15.8	16.4	17.0
Sulfur (total)	0.835	0.886	0.95
Trommel test number, %	90.5	89.5	89.63

The coking period is somewhat extended as the content of the concentrate in the charge increases. At the same time, the duration of the period depends on the conditions of coking. Therefore, it can be controlled to a certain extent by varying the conditions of coking.

During the wet quenching of coke iron, the iron becomes partly oxidized at exposed surfaces. The mechanical strength of the product is reduced. It is of great interest, therefore, to consider a dry quenching of coke iron. Our experiments in this direction were unsuccessful.

TABLE 2

Results of the Coking Operation

Items	Concentrate content in the charge %				
	0	10	20	30	40
Gas yield, m^3/ton . .	443	473	500	530	577
Heating value of the gas, kcal/m^3. . . .	4258	4104	4025	3819	3327
Metallic iron content, %.	0	7.56	15.1	22.3	30.0
Tar yield per ton of coal, ton	0.04	0.037	0.036	0.035	0.033
Light oil yield per ton of coal, ton.	0.0056	0.0057	0.0058	0.0067	0.0077
Coking period hr.	18.0	18.3	18.8	19.1	19.5

The gases involved and the chemical products were studied using laboratory, semicommercial and commercial plants. We carried out a number of experiments in which the concentrate content in the charge for coking was varied from 0 to 60%. The experimental results showed (Table 2) that, other conditions being equal, the time of the evolution of coke-oven gas gradually increases as the concentrate content decreases. The yield of gas per ton of coal increases and its heating value decreases as the concentrate content in the charge is increased. The over-all heating value of all the gaseous products per ton of coal charged increases.

The tar produced during the coking is decomposed under the catalytic action of iron oxide and metallic iron, the yield of light fractions being increased. As the concentrate content decreases, the yield of tar decreases, and that of benzene and phenol increases.

The extent of the reduction of iron during the production of coke iron increases as the temperature increases and as the length of the coking period increases.

For constant temperature and constant length of coking period, as the concentrate content increases, the amount of reduced iron for the same amount of carbon decreases but its total content increases.

From January till the end of April, 1955, we made pig iron from the coke iron in a blast furnace of 73 m^3 working volume. The results of the experimental smeltings showed that the consumption of coking coal per ton of pig iron was markedly reduced. In the production of pig iron with the use of coke iron obtained from the mixture consisting of 50% iron-ore concentrate and 50% coal, the coke consumption per ton of pig-iron decreased by more than 30% as compared with the production of pig iron with the use of ordinary coke. The average daily output of the blast furnace increased by 45-50%. In addition, the gas permeability of the blast furnace charge increased significantly and the distribution of the gas stream improved. As the content of iron ore concentrate in the coke iron charge increased, the conditions for the reduction of silicon became more favorable.

Industrial tests on coke iron were made in 1958 at the Khvankhé Factory. At the beginning of July, 1958, we began the production of coke iron, and on July 23, we introduced the coke iron (made from 10% concentrate and 90% coal, instead of ordinary coke) into the charge of one of the blast furnaces at the Khvankhé Works. The concentrate had the following chemical composition, (%):

Fe	SiO_2	Al_2O_3	CaO	MgO	P_2O_5	
56.88	20.04	1.19	0.59	0.30	0.15	0.055

The coal had the following composition, percent;

				S_{tot}
10.69	26.52	62.12	0.69	0.64

Lumpy iron ore of the following composition (in %) was also used for the pig-iron production:

Fe	SiO_2	Al_2O_3	CaO	MgO	P_2O_5	S
46.93	15.94	0.54	2.21	1.70	0.136	0.032

After fifteen days operation with the use of 10% coke iron, the furnace was charged with 20% and subsequently with 30% coke iron. At present, the furnace is being successfully operated with the use of 30% coke iron. The results of the smelting operation are given in Table 3.

As a result of the operation of the blast furnace it has been established that the production of pig iron from coke iron is possible. When coke iron was used, the temperature of the inwall of the furnace and the temperature of the peripheral gases decreased from 500 to 450-470 °C. The descent of the charge was speeded up. To reduce the contents of silicon and sulfur in the pig iron it is necessary to make slags of high basicity.

TABLE 3. Operation of the Blast Furnace with the use of Coke Iron

	Coke iron		
	10% (18 days)	20% (15 days)	30% (20 days)
Average daily output, tons	488	587	640
Consumption per ton of pig iron, tons:			
coke iron	1.1	1.2	1.3
lumpy ore	1.46	1.28	1.12
limestone	0.124	0.146	0.22
coking coal	1.366	1.250	1.187
Blast:			
consumption, m^3/min	1350	1300	1330
temperature, °C	600	650	700
pressure, atmos	0.88	0.85	0.87
Blast-furnace gas:			
temperature, °C	260	250	230
CO_2 content, %	8.2	7.0	6.7
Content in pig iron, %:			
silicon	1.20	1.27	1.29
sulfur	0.043	0.048	0.052
Slag basicity $\frac{CaO}{SiO_2}$	1.05	1.12	1.20

At present, we are working on the production and use of coke iron with a high content of iron-ore concentrate. The use of this coke iron will make it possible to reduce coal consumption to 1000 kg per 1 ton of pig iron and to achieve a ratio of blast furnace working volume to daily output equal to 0.7 or less. Special attention is being paid to the possibility of using local coal and anthracite for the production of coke iron.

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