THE USE OF CHINESE COKE AT BELGO-MINEIRA STEEL WORKS IN MONLEVADE [1]

Raimundo Nonato Batista Braga[2]
Vicente de Paulo Barroso Lamas[2]
José Alencar dos Santos[2]
Wander de Oliveira Borges[2]
Rodrigo Junqueira dos Santos[2]
Miguel Ângelo Quintão[2]
Aloísio Federman Caixeta[3]
Wilson Modesto da Silva[3]

Abstracts

The current situation of Chinese production of coke and coal is commented in this paper. It also shows the steps followed by Belgo's team when buying Chinese coke.

The improvement of Chinese coke quality is mentioned and the parameters related to first-class coke and Chinese slot oven and "beehive" coke are compared.

The situation of the world coke market is shown as well as the results of the experiment with 50% of Chinese coke in blast furnace burden.

---

(1) Paper to be presented at the " 1st International Meeting on Ironmaking ", Belo Horizonte, Brazil, September 24th to 26th, 2001

(2) Engineers of Belgo-Mineira, Monlevade Works

1 – INTRODUCTION

From 1990 on, Belgo started using coke in one of its blast furnaces. In 1993 the first team was sent to China, since 25% of the coke supply was supposed to be Chinese strategically. This was what actually happened from 1994 to 1999. Then it was decided to concentrate all the pig iron production of Monlevade steel works in a single blast furnace which had a capacity of 1,186m^3 of useful volume and an output of 3,000 ton/day, due to the obtained results and aiming at reducing costs.

This blast furnace started up in December 1999 with an annual coke consumption of 450,000 ton. The coke is fully imported and the supply is assured through two long-term contracts. Since then, Belgo has bought Chinese coke in order to complement the needs of coke beyond of what has been contracted.

This paper shows basically the quality of Chinese coke, the purchasing system of Belgo and the results of the experiment using 50% of Chinese coke in the blast furnace burden.

2 – THE COAL AND COKE FROM CHINA

China has a population of 1,25 billion inhabitants and has reached an economical growth of 10% a year in the last 18 years,

The coal reserves are 115 billion tons and that is the third biggest reserve in the world, after the United States and Russia. These reserves correspond to 11% of the world total production. Out of Chinese reserve, 65% are located in the province of Shanxi. The coal production is 1,50 billion tons/year, representing 34% of the world production.

Coke production for export is concentrated in Shanxi province, where there are hundreds of coke ovens with different capacity and most are "beehive" ovens.

The Chinese steel production has increased greatly as can be seen in table I. Meanwhile the coke production has increased too, reaching about 139 million ton/year in 1977, as shown in table II.

Producing that much coke, China has become a world exportation leader. In 1998 China exported 11 million tons (table III), especially to the European Community (3,50 million ton) as shows table IV. As the Chinese government has made environmental protection laws stricter, the coke production though "beehive" coke oven has decreased according to the following estimate[3], concerning coke export from China.

Year	% slot oven coke	% beehive coke
1999	30	70
2000	50	50

In June 2000, technicians from Belgo were informed in China that the Chinese government would no longer allow the construction and expansion of "beehive" coke ovens. The environmental restrictions regarding "beehive" coke ovens allied with transport issues - coke to harbor - have led to many shutdowns of minor coke ovens.

The government project is to stop "beehive" coke production in China by 2005.

At the time of that visit it could be noticed that several "beehive" coke ovens were shutdown and slot coke ovens were being built.

3 – THE PURCHASE OF CHINESE COKE BY BELGO

Belgo started buying Chinese coke in 1993, and as time went by the company realized that some special procedures and attention had to be applied due to product heterogeneity and reliability of the quality. According to Belgo's point of view that happened due to the diversified suppliers, manufacturing techniques, kinds of coke ovens, purchasing system, and especially to "spot" purchasing from several sources and the non-existing relationship between producer and buyer. Belgo's action plan to solve this problem could be divided in these steps:

- technical evaluation visits to the companies, coke ovens and laboratories;
- producer relationship and awareness of coke usage;
- operational inspection and procedures in the harbor where the; products were being sent from;
- inspection of the arrival harbor;

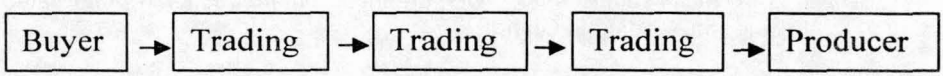
3.1 – TECHNICAL EVALUATION VISIT

Belgo's technicians have already visited about 20 coking plants and currently Chinese coke is bought exclusively from the coke ovens already visited, evaluated and approved by the company technicians. The supplying companies are classified according to an evaluation table as seen in table V. Only the companies classified as meeting over 80% of the requirements are considered suppliers. In addition to the company and coke oven evaluation, the laboratory in charge of the Chinese coke certification was also evaluated, considering their equipment, analysis procedures and sampling, as well as two series of interlaboratorial analyses which showed the non – existence of problems, according to results in table VI.

3.2 – PRODUCER RELATIONSHIP AND AWARENESS

Along the years of "spot" purchasing, the distance between buyer X producer was noticed to be great. The involvement only with the trading was not enough to get good quality coke. The awareness, the involvement and the commitment of the producer were very important to assure the quality and homogeneity of the product offered. An involvement with the producer was essential to get good quality coke. The buying X selling process should not be commercially attained and the so-called "Chinese coke" should be then called "coke-oven X from China". In the first semester of 2000 latest purchase, a lecture was given to the Antai company directory board and technicians, aiming at the producer involvement and awareness, when the importance of the coke quality was shown, as well as it effects in the blast furnace and the general problems related to Chinese coke. The operational inspection procedures and the handling of the coke in the warehouse and the harbor were also discussed with the producer and the trading.

Usually, the Chinese coke purchase has the following steps:



Belgo	Brazil	Abroad	China	China

Fig.1 – Shows an example of purchasing flow of coke by Belgo

3.3 – INSPECTION IN THE SENDING AND RECEIVING HARBORS

When the ship is being loaded, usually 2 Belgo technicians follow it up. Although it is not possible to follow up the loading for 24 hours, before starting the inspection, the operational procedures and Belgo's internal inspection system are discussed with the people responsible for the coke handling and for the sampling plan and sample collect. The warehouse and the harbor are inspected before and during the ship loading, and some batch could not be allowed to be loaded. Sometimes special sampling are carried out in the coke stored in the warehouse. Fig.2 shows a kind of handling that can occur and that demands the need of a strict harbor inspection.

Belgo uses "Praia Mole" harbor to receive the coke used at Monlevade steel works. All the ships are received with technicians follow up and the coke is sampled during the ship unloading. For the Chinese coke, several parameters related to quality have their penalty according to the evaluation carried out at Praia Mole. Belgo has a contract with SGS do Brazil for this.

3.4 – PURCHASING SYSTEM

Currently Belgo's purchasing policy of Chinese coke is ruled as:

- avoid purchasing from spot market;
- select coke ovens which produce over 150,000 ton/year, already approved by technical visits;
- select trading;
- confirm with producers the coke sale;
- assure in contract origin of purchased coke;
- avoid coke from over one coke oven. If from two coke ovens they should be loaded in different holds or they should be blended previously in the warehouse or it could be blended during handling to the harbor.
- be mentioned in contract operational procedures about handling of Chinese coke with minimized coke contamination and degradation and Belgo's inspection plans;
- have penalties for sending coke which do not meet quality requirements;
- purchasing long term contract, preferably;
- meet minimum delivery time, taking into consideration : production period, transport, screening in warehouse, and ship transport period;
- involvement and commitment in product quality: producer / "trading" / consumer;
- technical discussion with trading about inspection report related to the loading in China;

- regular contacts and technical visits producer / consumer
- development of coke ovens, aiming at long term contract;

4 – QUALITY OF CHINESE COKE

The quality of Chinese coke has undoubtfully improved along the years. The main parameters concerning the coke bought by Belgo can be seen in table VIII. Better stability regarding physical quality and low ash content can be noticed. In table VIII the quality of coke from a slot coke oven, with assured quality (first line) is compared to coke "X" from China, from slot and "beehive" coke ovens (data from 2000).

We can see:

- **Coke "beehive" "X" in relation to first class coke:**

  - Chemical compositions practically the same and S and P contents lower than first class coke.
  - CSR and CRI practically alike.
  - Higher physical strength and size distribution better than 1st class coke.

- **Slot oven coke "X" in relation to 1st class coke:**

  - Chemical composition practically the same and S content practically the same as P content lower than first class coke.
  - CSR higher and CRI lower.
  - Higher physical strength and size distribution practically the same.

- Regarding the difference between slot oven coke and beehive from "X" coke oven from China, the slot oven coke has higher CSR, smaller CRI and higher S content, lower physical strength and size distribution when compared to "beehive" coke.

5 – THE FUTURE OF COKE MARKET

Brazil depends on imported coke to supply about 10% of its consumption as follows:

Unit: ton x 10^3

Year	Coke production	Import	Domestic market	Consumption
1990	7,546	709	105	7,617
1998	7,894	1,639	43	8,257
1999	7,290	889	35	8,038

The three main coke suppliers are China (76% of world coke exports), Japan (18%) and Poland (6%). It seems quite certain that a shortage in coke production will occur but experts diverge about when. Some experts believe that in 2005 there will be a world shortage of coke (table IX).

6 – EXPERIMENT WITH 50% OF CHINESE COKE IN THE BURDEN OF BLAST-FURNACE

From 1994 to 1999 Belgo used regularly 25% of Chinese coke in its blast furnace charge, which had a useful volume of 406 m^3 and a production of 1,000 ton / day. In 2000 Belgo bought 32.000 ton of coke "X" from China, being 11,000 from this total from slot coke oven.

Due to low supply of 1st class coke, it was necessary to use Chinese coke up to 50% of "beehive" Chinese coke in the charge of the new blast furnace which has a capacity of 3,000 ton/ day. At the beginning 12% of this coke was used then 20, 25, 30 and 40% before reaching 50% finally. As the furnace accepted well the coke, the amount was being increased.

The bigger average size and the bigger mechanical strength of the Chinese coke allowed bigger coke to reach the lower parts of the furnace, thus improving its permeability and allowing a better control of thermal level and charge distribution. The use of "beehive" coke led to a lower fuel consumption, considering however the lower rate of pulverized coal injection at the time (125 kg/ THM). Regarding slot oven Chinese coke, a better permeability of hearth was noticed, shown by the sub-hearth temperature. (table X)

In relation to slot oven coke, the consumption period was shorter and the amount was 25%. The consumption was basically the same as well as the permeability and thermal control.

Table X shows the experiment results that shows the better coke performance ("beehive") in relation to slot oven coke.

7 – CONCLUSIONS

i. From 1994 to 1999 Belgo used regularly 25 % of Chinese coke in its blast furnace burden (capacity of 1,000 ton/day) without any negative consequence;

ii. Within the conditions which the experiment in the 3,000 ton/day blast furnace was carried out, it could be seen that it is possible to use 50% of Chinese "beehive" coke (without any disadvantage in performance) conveniently, and it could even be beneficial in some aspects;

iii. Chinese coke is a supplying good alternative due to its attractive price, higher mechanical strength and lower alkali content;

iv. Due to environmental restrictions the production of "beehive" Chinese coke tends to decrease substantially.

v. Through the purchasing system and producer involvement it is possible to improve considerably the reliability and quality of Chinese coke;

vi. The heterogeneity of Chinese coke is basically linked to the diversified supplying sources and to the companies purchasing system.

vii. The presence of Belgo's technicians in China during loading and shipping and the producers awareness have contributed strongly to assure the quality improvement of Chinese coke bought by Belgo.

8 - BIBLIOGRAPHY

1 – International Energy Agency Coal in the energy supply of China. Londres: 113 p.

2 – BARRON, M. Asia's coke giants – doing business with them. Coke Outlook 2000. Chicago, EUA. October 11th to 13th, 2000.

3 – HUA, Z. Outlook of the World coke market and Chinese coke exports. Coke Outlook 2000. . Chicago, EUA. October 11th to 13th, 2000.

4 – BRAGA, R. N. B., Lamas, V. de P. B. Relatório de visitas à coquerias e portos na China. Companhia Siderúrgica Belgo-Mineira. Junho de 2000. João Monlevade. MG

TABLE I – ANNUAL PRODUCTION OF STEEL IN CHINA

Year	Steel Production (ton)
1949	158,000
1957	5,350,000
1975	23,900,000
1980	37,120,000
1990	55,000,000
2000	125,000,000

TABLE II – ANNUAL PRODUCTION OF COKE IN CHINA[3]

Unit: ton x 10^6

Year	World production	Production of Coke in China		
		Slot oven	Beehive	Total
1992	333	56	24	80
1993	331	60	33	93
1994	345	60	54	114
1995	369	65	70	135
1996	361	70	66	136
1997	366	71	68	139
2000*	326	80	39	119
2005*	277	90	10	100

* estimate

TABLE III – ANNUAL EXPORTS OF CHINA COKE [3]

Year	Exported amount (ton x 10^6)
1985	0.336
1990	1.126
1994	4.040
1995	8.860
1996	8.510
1997	10.580
1998	11.460
1999	9.974

TABLE IV – DESTINATION OF CHINESE EXPORTS IN 1999[3]

Country / Region	Amount (ton x 10^3)	%
European Community	3,534	35
India	1,247	13
The United States	1,122	11
Japan	1,053	11
Brazil	543	5
Others	2,475	25
Total	9,974	100

TABLE V – COKE OVEN EVALUTION FORM – EXAMPLE

Score : 0 – 10, per item

Item	Weight	Coke oven A	Coke oven B
1 – Meeting Belgo's specifications	5	10	10
2 – Amount specified delivered	5	10	5
3 –Technical requirements	4	8	5
4 – Company structure – reliability	4	9	5
5 – Coke oven organization	3	8	8
6 – Laboratories	4	7	7
7 – Transport and storage system	3	8	6
8 – Industrial facilities	3	9	5
Total	310	298	200
%	100	87	65
Approval	-	Yes	No
Kind	-	Beehive	Beehive
Trading	-	X	Y

TABLE Vi – RESULTS OF INTERLABORATORIAL ANALYSES CHINESE COKE -1998

Parameters	SAMPLE A		SAMPLE B	
	SGS Brazil (%)	SGS China (%)	SGS Brazil (%)	SGS China (%)
Ash	10.48	10.69	10.56	10.40
V. Matter	1.46	1.30	1.12	1.20
Fixed Carbon	88.06	88.01	88.32	88.40
S	0.46	0.47	0.49	0.46
P	0.008	0.008	0.007	0.009
SiO_2	55.40	52.54	55.11	54.86
Al_2O_3	35.19	36.02	34.23	34.26
K_2O	0.50	0.62	0.65	0.69
Na_2O	0.46	0.48	0.35	0.31
MgO	0.45	0.51	0.57	0.54
Mn_3O_4	0.033	0.037	0.137	0.130
Fe_2O_3	3.56	3.82	3.57	3.89

Sample A: Coke A – collected in Brazil – prepared by SGS Brazil
Sample B: Coke B – collected in China – prepared by SGS China
The SiO_2 to Fe_2O_3 contents refer to ash contents.

TABLE VII – FEATURES OF CHINESE COKE BOUGHT BY BELGO FROM 1994 ON [4].

Parameter	Coke A		Coke B		Coke C		Coke D		Coke E		Coke F	
	Loading port	Praia Mole	Loading port	Praia Mole	Loading port	Praia Mole	Loading port	Praia Mole	Loading port	Praia Mole	Loading port	Praia Mole
F.Carbon	87.41	85.15	87.78	86.69	88.50	86.34	88.48	89.11	88.58	88.55	88.68	88.83
V. Matter	1.24	1.24	1.24	1.30	1.20	1.43	1.33	1.34	1.23	1.12	1.50	1.10
Ash	11.35	13.61	10.98	10.80	10.30	12.23	10.19	9.55	10.19	10.32	9.82	10.07
S	0.46	0.49	0.54	0.51	0.57	0.47	0.44	0.46	0.46	0.49	0.50	0.54
P	0.02	0.03	0.018	0.017	0.018	0.012	0.012	0.010	0.009	0.007	0.008	0.007
SiO_2		53.76		55.73		42.56		54.77		57.90		53.99
Al_2O_3		33.04		32.26		28.37		32.75		26.89		31.89
Alkalis		1.20		0.76		0.52	1,15	1.14	0.75	0.82		1.00
< 25		27.12	3.90	10.81	3.80	22.71	2.19	13.37	1.19	8.43	0.98	8.12
Mean size		41.20	59.87	51.92	62.61	46.73		48.38	61.32	50.87		52.25
CSR	66.60	63.32	72.20	65.40	67.50	68.13	63.90	65.89	69.30	62.61	64.90	67.80
CRI	22.00	25.39	19.20	19.50	19.10	18.34	23.10	24.05	19.80	21.50	20.10	22.10
DI^{150}_{15}	87.30	88.95	84.00	88.40	90.50	93.40				89.42		89.10
M40	90.40	90.18	92.60	92.10			89.39	92.93	93.40	93.54	94.20	94.20
Laboratories		SGS	C. NKKK	A. H. Knignt	A. H. Knignt	SGS	SGS	SGS	SGS	SGS	SGS	SGS

TABLE VIII – COMPARISON BETWEEN FIRST CLASS QUALITY COKE AND CHINESE COKE

Unity: %

PARÂMETER	FIRST CLASS COKE					COKE " X " FROM CHINA							
						BEEHIVE					SLOT OVEN		
	5000 L 1	5000 L 2	5000 L 3	26000 L 4	**Average**	5000 L 1	5000 L 2	5000 L 3	5000 L 3	**Average**	5000 L 1	5000 L 2	**Average**
FIXED CARBON	88.37	88.49	88.54	88.59	**88.54**	88.23	87.72	88.26	88.68	**88.22**	88.35	88.33	**88.34**
VOLATILE MATTER	1.21	1.13	1.05	1.05	**1.08**	1.10	1.21	1.29	0.92	**1.13**	1.43	1.34	**1.39**
ASH	10.22	10.18	10.21	10.16	**10.18**	10.57	10.87	10.46	10.40	**10.58**	10.23	10.32	**10.28**
S	0.59	0.61	0.62	0.67	**0.65**	0.44	0.49	0.48	0.43	**0.46**	0.60	0.63	**0.62**
P	0.030	0.034	0.030	0.030	**0.031**	0.010	0.011	0.011	0.011	**0.011**	0.007	0.008	**0.008**
ALKALIES					**1.60**					**0.74**			**0.73**
CSR					**63.19**					**66.00**			**69.70**
CRI					**25.95**								
DI_{15}^{150}	88.07	89.73	83.47	84.07	**85.23**	88.07	89.73	89.43	87.77	**88.75**	87.37	87.63	**87.50**
M 40	87.60	88.40	88.00	87.10	**87.39**	93.00	93.00	93.60	93.00	**93.15**	92.80	92.80	**92.80**
M 10	6.20	6.60	6.40	6.20	**6.28**	4.60	4.40	4.40	4.40	**4.45**	4.60	4.40	**4.50**
Mean size (mm)	49.31	51.79	52.13	51.75	**51.49**	53.32	55.16	58.90	58.93	**56.58**	47.57	54.44	**51.01**
> 90 mm	1.86	2.61	3.44	0.94	**1.54**	0.00	0.77	0.33	0.89	**0,49**	0.53	0.00	**0.26**
> 75 mm	6.95	10.68	11.43	7.37	**8.14**	8.42	7.98	12.72	15.58	**11.17**	2.68	5.38	**4.03**
< 25 mm	5.33	3.47	2.81	1.54	**2.37**	4.97	3.60	0.33	2.70	**2.90**	2.56	0.74	**1.65**
< 10 mm	3.11	1.84	0.92	0.40	**0.96**	1.87	0.96	0.17	0.81	**0.92**	1.33	0.33	**0.83**

The results refer to Praia Mole harbor sampling in Brazil, except to CSR and CRI which are results of loading port harbor, "5000 L1", means batch 1 from 5000 t; "5000 L2" means batch 2 from 5000 t, etc.

TABLE IX– COKE CONSUMPTION AND WORLD DEMAND

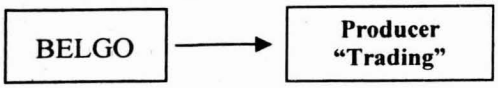
Unit: ton x 10^6

Year	Coke production		Demand	Difference
	World	China		
1997	366	139	347	+ 19
2000	326	119	328	- 2
2005	277	99	343	- 66

TABLE X– RESULTS FROM BLAST FURNACE "A" WITH COKE " X " FROM CHINA "BEEHIVE" AND SLOT OVEN

Parameter	50% beehive coke	25% slot oven coke
Production (THM / day)	3,007	2,999
Productivity (THM / m^3 /day)	2.22	2.21
Coke rate (kg / THM)	372	376
Coal rate (kg / THM)	126	128
Fuel rate (kg / THM)	498	504
Hot metal temperature (° C)	1,506	1,501
Sub-hearth temperature - 5.40 m (° C)	397	328
Si content (%)	0.49	0.45
S content (%)	0.030	0.034
P content (%)	0.092	0.083
Blast temperature (° C)	1,094	1,080
O_2 enrichment (%)	4.05	4.18
Blast moisture (g / Nm^3)	25	22
Sinter in the burden (%)	82	77
Lump ore in the burden (%)	13	16
Pellets in the burden (%)	5	7

A – SUPPLIER A



B – SUPPLIER B

C – CHINA

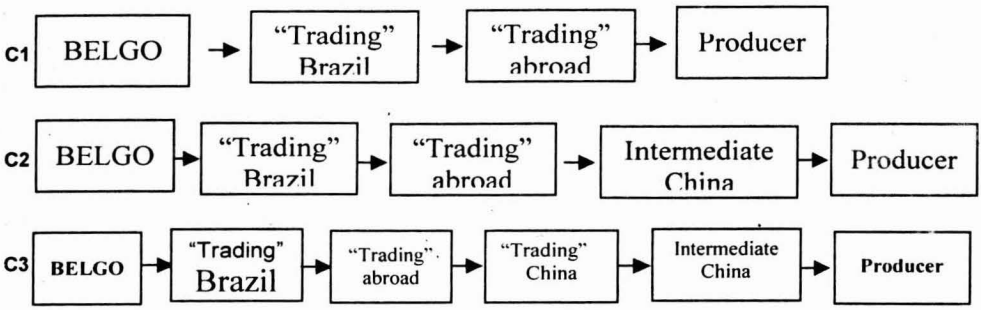
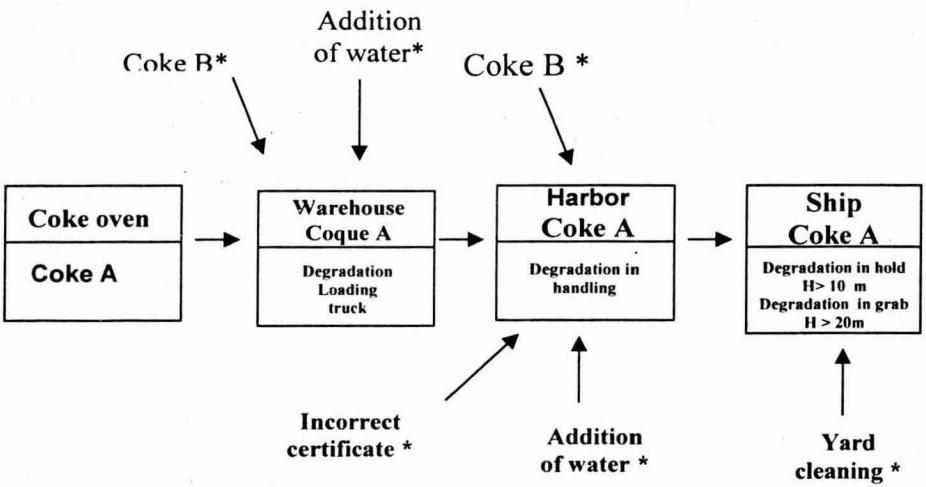


FIG.1 – BELGO'S COKE PURCHASING FLOW



* Negative activities – decrease values

FIG. 2 – FLOW OF COKE "A" HANDLING IN CHINA, FROM THE COKE OVEN TO THE SHIP