USING PULVERIZED COAL AS AN ALTERNATIVE ENERGOTEHNOLOGICAL SOURCE TO PRODUCE PIG-IRON FOR STEELMAKING

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Abstract

Blowing in furnace pulverized coal is made in order to reduce coke consumption, to replace liquid fuels and natural gas, ensuring a stable operating system, increasing economic efficiency and improving environmental conditions.

This paper presents an economic and technical calculation, demonstrating and justifying for the introduction to Arcelor Mitall Galați blast furnaces of pulverized coal as a substitute for coke.

There were taken into account the Jiu Valley coal (type PALD to semi coke), non-agglutinates, especially cleaned.

There were technological calculations performed in two variants, namely the first one where it was taken into account 50 [Nm3 methane] and 50 [kg coal] (coal dust) and the second one which considered 100% coal dust, i.e. 125 [kg coal]. The economic benefits are obvious, technical specific consumption of coke decreased from 508.7 [kg / t] on 455.0 [kg / t] (for variant II).

Keywords: pig-iron for steelmaking, pulverized coal, alternative energy sources, specific consumption of metallurgical coke

1. Introduction

Currently in the world is tending towards a dramatic specific consumption of coke per ton of iron in coal dust blowing at the wind mouth of the blast furnace.

Blowing in pulverized coal in blast furnace is making to reduce consumption of coke, the replacement of liquid fuels and natural gas, ensuring a stable operating system, increase economic efficiency and improve environmental conditions.

In parallel with the expansion process has increased interest in knowing the factors controlling coal dust injection (CPI), which conducts research, intended to optimize the process.

Technical blowing of coal dust in the blast furnace has been developed in both Europe and America. Auxiliary fuel has been blowing up around the 60s, being experienced with fuel oil, natural gas and coal. Of these, the fuel oil proved to be the best auxiliary fuel but when oil crisis started it came to using coal.

This technology is currently applied more than 100 blast furnaces worldwide, of which 44 are in Western Europe.

In table 1 are presented some of the blast furnaces which are operating with this technology, the criterion upon which were chosen for these furnaces operational data (from a much larger number) was to achieve a specific highest consumption of coal.

Table 1. Main blast furnaces which use operating systems with coal dust blowing.

Country	Company	Crucible diameter, [m]	Blowing system	The year start of installation	Average coal consumption, [kg/t pig iron]	Coal consumption, [kg/t pig iron]	Coke consumption, [kg/t pig iron]
Germany	Thyssen	13,6	Kutner	1987	140	145	307
	Dillingen	11,0	Paul Wurth Rotary	1986	100	-	363
	Krupp	11,5	Kutner	1987	100	100	390
France	Sollac	14,0	Paul Wurth Rotary	1986	100	100	385
	HFRSW	7,0	Sprunck	1982	80	80	395
Netherlands	Hoogovens	11,0	Armco	1983	120	140	383
England	BSC	8,9	Simon-Macawber	1985	92	109	375
Belgium	Sidmar	10,0	Paul Wurth Rotary	1987	110	120	397
Luxembourg	Arbed	8,0	Paul Wurth Rotary	1990	stopped	84	467
USA	Armco	10,2	Armco	1973	90	120	390
South Korea	Posco	13,2	Armco	1987	65	75	398
Japan	NSC	13,8	Armco	1985	81	101	392
	Sumitomo	11,1	Sumitomo	1986	87	104	405
Romania	Galati F4	9,1	Kutner	1996	150	170	430
	Galati F5	11,6	Kutner	1996	150	170	430

Advances obtained in recent years with coal dust blowing in blast furnaces, concerning both security and operational facilities of the blast reached as state of the art in the blast furnace can accept only specific consumption of coke 300kg/t pig iron.

Currently, efforts are to succeed in instilling 250 kg coal/t iron in large furnaces, which could lead to a coke consumption of 250 kg coke /t pig iron.

Average operating parameters of blast furnace States of the European Union (EU) are presented in table 2. Table 3 shows the operating parameters of the furnace 5 from SC ARCELOR MITTAL SA Galati compared with those of some EU blast furnaces.

The preference observed of using coal or blends with an average content of volatile material (VM) is signaled and furnace performance using coal with a high content of VM. Feature is the limited amount of slag too (216 - 306 kg/t pig iron) and produced relatively low silica content (0.34 ... 0.69%) of pig iron.

In comparison, the parameters ARCELOR MITTAL SA Galati SC F5 indicates a specific consumption of coke average of 461kg/t pig iron and 102 kg PC/t pig iron, so a higher total fuel consumption by 60 ... 75 kg/t pig iron, a difference which is reflected at all levels of instilling charged and PC helps to limit the quantities of infused effective.

Table 2. Average operating parameters of blast furnace with coal instilling in the European Union

Name	UM	Germany	Belgium	France	Netherlands	Italy	England
Blast furnaces	-	7	6	8	2	3	3
Diameter Crucible	m	11,34	9,73	10,31	12,4	11,60	8,78
Workload	m^3	2252	1754	2100	3059	2551	1443
Using	%	97,6	97,3	95,2	96,1	98,0	98,0
Daily production	t/24h	6076	4096	4431	8140	7297	3333

User index	t/m^3, 24h	2,36	2,33	2,11	2,66	2,86	2,31
Coke consumption	kg/t pig iron	361	386	351	335	354	347
PC instilling	kg/t pig iron	115	128	129	164	146	151
M.V.$^{x)}$ coal	%	28,7	26,3	21,8	39,1	25,2	18,2
Charging:							
agglomerate	%	72,49	82,21	87,21	47,20	74,27	73,61
pellets	%	17,71	9,90	0,30	49,62	17,51	7,50
iron ore	%	9,54	7,83	11,88	3,18	8,22	18,81
others	%	0,26	0,06	0,61	0	0	0
air temperature	^oC	1175	1112	1172	1198	1182	1120
oxygen in the air	%	23,6	24,0	22,6	25,7	25,2	26,6
flame temperature	^oC	2182	2187	2138	2165	2146	2237
Pig iron:							
silicon	%	0,53	0,58	0,48	0,41	0,63	0,59
sulfur	%	0,043	0,043	0,026	0,039	0,029	0,030
pig iron temperature	^oC	1495	1480	1481	1509	1504	1478
slag	kg/t pig iron	283	274	306	216	293	277

Table 3. Average operating parameters of blast furnace with coal instilling in the UE and SC ARCELOR MTTAL GALATI

Name	**UM**	**Galați F5**	**Thyssen Hamborn F9**	**Sidmar Gent F.A**	**Sollac Dunkuerque F.4**
		Romania	**Germany**	**Belgium**	**France**
Diameter Crucible	m	11,6	10,2	10,0	14,0
Workload	m^3	2560	1833	1776	3648
User Index	t/m^3, 24h	1,777	2,68	2,77	2,40
Charging:					
agglomerate	%	78,71	70,87	91,45	80,48
pellets	%	12,64	18,50	6,87	-
iron ore	%	8,65	5,29	1,62	19,52
others	%	-	5,34	0,06	-
coke consumption	kg/t pig iron	461	338	303	316
coal consumption	kg/t pig iron	102	141	181	174

M.V. coal	%	~ 35	25,7	26,6	20,6
oxygen in the air	%	23,19	23,7	24,5	23,6
air temperature	^oC	1050	1132	1209	1210
flame temperature	^oC	2210	2155	2187	2114
Pig iron:					
silicon	%	0,77	0,408	0,38	0,338
sulfur	%	0,025	0,038	0,018	0,026
pig iron temperature	^oC	1494	1503	1488	1491

2. Theoretical background of opportunity and economic efficiency of blast furnace operation nr. 5–Arcelor Mittal Galati with methane gas and coal dust for a version of reference.

This paper presents a techno-economic calculation, demonstration and justification for the introduction of the blast furnaces of Arcelor Mitall Galati with pulverized coal as a substitute for coke in the reduction of energy consumption of coke and for the pig iron development.

Were taken into account the Jiu Valley coal (type PALD to semi coke), non-agglutinates, especially cleaned. Technological calculations were carried out in two variants namely, the variant I which they found 50 [Nm^3 methane] and 50 [Kg coal] (coal dust) and variant-II which were considered 100% coal dust, 125 [kg coal]. It was adopted for calculating the replacement ratio 0.96 [kg coke / kg coal].

Table 4. The indicators of blast furnace nr. 5 - Arcelor Mittal Galati for the variants calculated at the work

Nr.	**Indicator [u.m]**	**Component charging**	**Variant reference**	**Variant proposed -I-**	**Variant proposed -II-**
1	Charging [Kg/t pig iron]	agglomerate pellets mangan ore ore from Brazil - TOTAL	1327.5 484.4 7.6 - 1819.5	1327.5 484.4 7.6 - 1819.5	1341.9 484.4 7.6 - 1833.9
2	[Kg/t] [Nm^3/t] [Kg/t]	technical coke CH_4 anhydrous coal TOTAL	508.7 53.9 - 562.6	455.0 50 50 555.0	430.0 - 125.0 555.0
3	Air blow [Nm^3]	calculated flow humidity oxygen temperature [^0C]	1336.5 1 22 970	1168.21 1 24 1200	1202.1 1 23.5 1200
4	[t pig iron /m^3 effective day]	Iu	1.165	1.805	1.80
5	[t pig iron /m^3 effective day]	Ia -coke combustible	0.59 0.654	0.8213 1.00	0.778 1.00
6	[%]	pig iron removal	55	55	54.53
7	Reduction FeO	Rd / Ri η_{CO} η_{H2}	42/58 44.8 32.5	40/60 46.3 30.0	40/60 46.77 32.0
8	Blast Furnace Gas	[Nm^3/t] CO_2 [%] CO [%] H_2 [%]	1888 18.35 22.64 4.01	1749.33 19.76 23.18 5.96	1760.7 20.0 23.3 4.5

9	Pig iron quality	Si [%] Mn [%] S [%] C [%]	0.84 0.88 0.023 4.55	0.84 0.88 0.023 4.55	0.84 0.88 0.023 4.55
10	Slag	[Kg / t pig iron] CaO/SiO_2 $(CaO+MgO)/SiO_2$	451.9 1.25 1.33	451.6 1.25 1.33	466.0 1.32 1.419
11	Heat	10^3[Kcal/t]	2535.9	2566.55	2606.22
12	Heat resources	oxidation C oxidation H_2 Q air	79.0 4.0 17.0	76.7 4.7 18.6	77.0 4.0 18.8
13	Heat balance	η_t[%] η_C[%] difference [10^3Kcal/t]	87.1 61.0 192.1/7.6	87.52 62.13 194/7.5	87.63 69.94 196/7.5
14	Replacement ratio	A[Kg/Nm^3CH_4] B - - A - - B - -	1.07 0.87 - -	1.01 0.82 0.97 0.89	- - 0.98 0.95
15	Theoretical temperature of combustion zone	[^{0}C]	1809	1947	1996

3. Conclusions from data obtained through technology calculations.

For these calculations took into account the fact that the blast furnace will operate up to a normal combustion including normal heating capacity of the cowpers . It was also considered add O_2 so it maintains a proper temperature and can obtain replacement favorable reports.

The economic benefits are seen from the following: - specific consumption of technical coke decreased from 508.7 [Kg/t], (the operation of the blast furnace in March 2009 to 455.0 [Kg/t], for variant-II). It can be seen that the total amount of fuels decreased from 562.6 to 555.

Calculation assumptions are aprons and it can count reality on higher fuel economy since they have retained some heat reserves that could cover possible variations where coal would be uneven if the composition or conditions blasting would not be the best. Savings in coke consumption respectively of total fuel consumption due to a normal furnace operation to correct movement and a reducing gas, which is not the case in the present, when the furnace is running abnormally slow, the resulting movement unilateral gas. In addition it provides a fair system of temperature in the wind mouth through the air preheat.

At 1200 ^{0}C the temperature corresponding to the normal characteristics of Arcelor Mittal Galati cawpers and additions of O_2 in the air breathed in conjunction with fuel quantities no auxiliary instilling.

CO yield (η_{CO}) increased from 44.6 to 46.77 and H_2 yield had a slight decrease in the variant I. We conclude that the yields obtained were comparable to those performed on furnaces such as those in Germany, USA, Japan and others. Depending on the yields we obtained a proportion between direct and indirect reductions (from FeO to Fe) of about 40/60.

The iron quality remained the same as the operation of the furnace in the reporting period, the slag were seen in a small increase in the quantity version 100% coal.

Coke replacement ratio of auxiliary fuel could be increased from 0 to 1.01 and 0.97 (for option-I-), including 0.98 (for variant-II).

From the above, we believe the most plausible option for the blast furnaces at Arcelor Mittal Galati SC. as-I-option, but may be imposed and the variant-II for economic reasons.

It is desirable that all variants operating and blowing air preheating system is kept near the normal level of 1200 ^{0}C and not to accept significant reductions of air preheat temperature as is the case now, with effects disadvantages for the blast furnace and the integrity of gratings from refractory superior materials of cawpers.

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