International Journal of Mineral Processing and Extractive Metallurgy
2016; 1(4): 41-45
http://www.sciencepublishinggroup.com/j/ijmpem
doi: 10.11648/j.ijmpem.20160104.14

Some Improvements's Impact in the Enhancement of Ferrochrome Smelting Parameters in Elbasan, Albania

Dr. Agron Dhima[1], Msc. Ruzhdi Domi[2]

[1]Materials Engineering Division, Facultyof Mechanical Engineering, Polytechnic University of Tirana, Tirana, Albania

[2]Head–Engineer, Ferrochrome Plant, Elbasan, "AlbChrome", subsidiary of "BALFIN" Group, Albania

Email address:
agron_dhima@yahoo.com (Dr. A.Dhima)

To cite this article:
Dr. Agron Dhima, Msc. Ruzhdi Domi.Some Improvements's Impact in the Enhancement of Ferrochrome Smelting Parameters in Elbasan, Albania. *International Journal of Mineral Processing and Extractive Metallurgy.*Vol. 1, No. 4, 2016, pp. 41-45.
doi: 10.11648/j.ijmpem.20160104.14

Received: September 6, 2016; **Accepted:** September 10, 2016; **Published:** September 30, 2016

Abstract: Ferrochrome Smelting Plant in Elbasan, Albania produces High Carbon Ferrochrome since the late 80's. During the last 2 years it is managed by "AlbCHROME", subsidiary of "BALFIN" Group, which conducted a good amount of reconstructions and technological changes in the plant. This paper presents a general assessment on the impact of the improvements carried out to enhance the technical and economic parameters, through the analysis of the applied technology, the effectiveness of the processing of raw materials, product quality available and possible ways to reduce the cost of production. The assessment is based on the monitoring of industrial production during the first Quarter of 2016, on relevant data, confronted to the literature data and on the experience of the authors.

Keywords: Ore, Coke, Ferrochrome, Smelting, Submerged Arc Furnace, Slag

1. Introduction

Till 2013, based on the Agreement with the Albanian Government, the company"ALBANIAN CHROME (ACR)" had the concession right to produce High Carbon Ferrochrome in Elbasan Plant. Later, the right of concession was given to "BALFIN" Group through its Subsidiary "AlbCHROME", which carried enough reconstructions and technological changes in the plant, mainly in the two submerged arc furnaces, with the power 9 MVA each, and in casting technology.

This paper presents the results comparing two technological production periods, regarding specific technical, economic and managerial aspects, and concludes with some recommendations for the stabilization and continuous improvement of production efficiency and quality of finished products.

2. Comparison of Results "ACR" – "AlbCHROME"

The purpose of comparing the results in the production of Ferrochrome in Elbasan, achieved by the Company "ACR", with those achieved by "AlbCHROME", is to make in evidence the positive impact of economic and technical improvements in furnaces Nr. 2 and No. 3, performed by "BALFIN" Group.

2.1. Technology and Material Balances in ACR"

According to the "Technological Rules in ACR" of the year 2008 [1], the production of High Carbon Ferrochrome in Elbasan based on the mixture of the Albanian ore from the mine of Bulqiza with a South African ore, the latter aimed at improving the slag's chemical composition, lowering its melting temperature and viscosity. The Bulqiza ore was mixed with South African ore in the proportion 70% / 30%, reaching a 38% Cr_2O_3 content. The Quartz was used as flux in reduced quantities, to achieve SiO_2 content in the slag about 35%. The best results were achieved with the use of a high-quality Australian coke as reducing-material. One single tap hole was used for metal and slag. The results of the theoretical Material Balance of "ACR", are presented in Table 1.

The figure 1 presents the general outline of Elbasan's submerged arc furnace with transformer power of 9 MVA and the location of metal and slag tap holes.

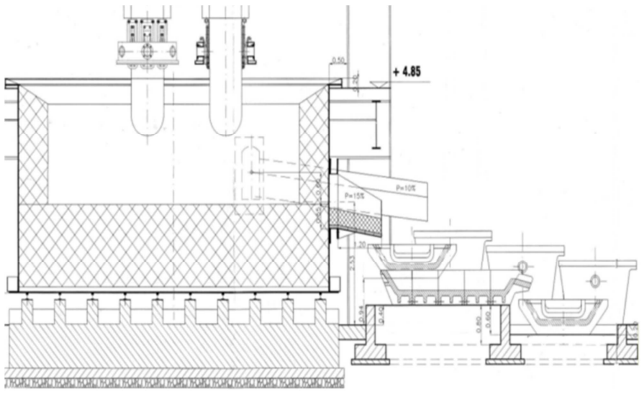

Figure 1. *Submerged arc furnace 9 MVA.*

Table 1. *Theoretical Material Balance of "ACR" per 1 ton Fe-Cr.*

Income			**Outcome**		
Dry materials	**Kg**	**%**	**Products**	**Kg**	**%**
Bulqiza ore + South African ore	2643	75.9	Ferro-Chrome	1000	28.7
			Slag	1581	45.4
Recycled metallic waste	263	7.6	Various	900	25.9
Sum	2906	83.5	losses		
Coke	463	13.3	(smoke, dust, etc.)		
Quartz	112	3.2			
TOTAL	3481	100	TOTAL	3481	100

The Cr Recovery was 85–87%. The Ferrochrome produced comprised above 60% Cr and C, S and P according to norms of the Standard ISO 5448 [2].

2.2. The Technology and Material Balances for Period January-March 2016 in "AlbCHROME"

The main technological improvements achieved by "Albchrome" are as follows:

- two separate tap holes in the furnace, one for the metal and one for the slag, where the slag tap hole is positioned 500 mm above the metal tap hole and with the angle of 60 degrees from it;
- improvement of slag-forming process;
- reconstruction and initiation of the new line of briquetting;
- two projects to increase furnace power transformer from 9 MVA to 12.5 MVA and for slag granulation.

The load consists of Bulqiza ore and ores supplied by third parties wich have brought a huge amount of fines (up to 40%).The Quartz (originated from Pogradec, Albania) is used as flux, in nearly equal amount for coke, for achieving 42-43% SiO_2 in the slag. The coke supplied by Bosnia and Germany has shown some quality problems, discussed below. The table 2 shows the results of actual Material Balance, calculated according to the data provided by the Plant documentation [1] for the first Quarter of 2016.

Table 2. *.Actual Material Bilance of "AlbCHROME" Elbasan per 1 Ton Fe-Cr during the first Quarter of 2016.*

Income			**Outcome**		
Dry materials	**Kg**	**%**	**Products**	**Kg**	**%**
Bulqiza ore+ ore	2785	75.8	Ferro-Chrome	1000	27.2
by third parties			Slag Various	1864	50.8
Coke	457	12.4	losses	808	22.0
Quartz	430	11.8	(smoke, dust, etc.)		
TOTAL	3672	100	TOTAL	3672	100

The Cr Recovery was about 92.5%. 8126 tons Ferrochrome with 68.9% Cr were produced.

P.S.: Since April 2016 the production of briquettes started with the new line, which has a capacity of 6 ton/hour.When there are largeamounts of fines, a quantity of briquettes up to 35% of the overall load can be produced / used.

2.3. Results Comparison

The results of the period after the reconstruction of furnaces in Elbasan ("AlbCHROME" operation), compared with those before the reconstruction, are clearly better. Specifically, for the first Quarter of 2016, we notice:

- Cr Recovery: 5-7% higher;
- Ferrochrome produced: 7-8% more qualitative (because of better refinement conditions, due to longer metal's remaining time in the furnace);
- Ore specific consumptions per ton Fe-Cr: about 4% lower, while the ores in both periods were similar;
- Possibilities to use more fines in the furnace load;
- Similar specific consumptions of coke per ton Fe-Cr, although a few years ago,the Australian Coke had been of high quality.
- These improvements are primarily a result of the two separate tap holes for metal and slag,of slag-formationprocess improvementand of improvement of management in general.

3. Specific Technological, Economic and Managerial Aspects

3.1. Chrome Recovery

By specialists [3], [4, [5] is considered that Cr Recovery, calculated as follows:

$$\text{Recovery of Cr } \% = \frac{\text{Cr in Ferrochrome}}{\text{Cr in ore}} \text{ x } 100\% \qquad (1)$$

is the main factor of metallurgical efficiency in the production of Ferrochrome. The Cr Recovery of 92.5% during first Quarter of 2016, compared with this indicator for many foreign manufacturers, is fairly good, but it could be expected a level of 93%.

3.2. Electricity Consumption

According to the specialists [3], [4], [5] it is considered

that the specific consumption of Electricity is the main factor of energy efficiency in Ferrochrome production. Currently the consumption evidenced at 4309 kWh / ton Fe-Cr, which is a level close to that recommended (4300 kWh / ton of Fe-Cr) according to [4] for Elbasan Plant and reasonable if we take into account the quality of raw materials and the capacity of the furnaces.

This indicator would be improved even more with the increase of power transformers (project under implementation) and with the increase of Cr Recovery.

3.3. Ores Quality

The gradual impovrishement of Albanian chromites and the increase of fines amount greatly affects the profitability of the production of Ferrochrome. Many years ago, the Albanian Chrome ores were characterized by an average of Cr_2O_3 = 40.5% according to [5]. While in 2014 the specialists in [4] classified the Albanian ores and concentrates as follows:

Table 3. *Chemical composition of ores and concentrates of "AlbCHROME", %.*

Materials	Cr_2O_3	FeO	SiO_2	Al_2O_3	MgO	Cr/Fe
Qualitative ore	40 –42	11.8	11.5	8.0	23.5	3.0
Moderate ore	36 – 38	12.5	15.0	7.0	23.0	2.7
Poor ore	30 – 34	10.0	18.0	7.0	27.0	2.6
Qualitative con-centrate	48 – 50	13.93	7.0	9.37	17.94	3.0
Moderate conce-ntrate	45 – 47	13.93	9.0	9.37	18.20	3.0

In general, the Elbasan Plant is supplied with lumpy ores of moderate quality, fines of poor quality and few concentrates. The plant is supplied with considerable amount of fines and it is recognized that the use of over 30% of fines in the load worsens the technology performance and theconsume of Electricity [4], because the process difficulties, the blockage of gases exit, the increase of losses from the transfer of fines with gases and from mixture of metal with the slag. But it should be noted that this is a global trend, even according to [3] and [5], 75-80% of chromites in the world are in form of fines of less than 10 mm.

3.4. Ferrochrome Quality

The quality of the finished product "High Carbon Ferrochrome" is assessed through the completion of the technical requirements of Standard ISO 5448 by [2] in terms of chemical composition, weight, granulometry, limited amount of fines and cleanliness from slag and various impurities.

We analyze below some problems evidenced during the first Quarter of 2016, regarding the deviations from the standard of some chemical elements, which in some way negatively affect the profitability of production because of the lowering the sale prices of Ferrochrome.

In general,% of Cr in Fe-Cr are quite high (approximately 68.9% Cr during the first Quarter of 2016), which supports high sale prices of Fe-Cr. Carbon and Silicon also does not pose any problem. The problems, which are worth analyzing and consistently resolved are associated with the content of sulfur and phosphorus. For Ferrochrome marks, produced in Elbasan, ISO 5448 standard requires P content less than 0.05%; S content less than 0.05% or more than 0.05% but less than 0.10%. Understandably, the lower the P and S contents are, the higher the aim for the maximum sale prices.

The specialists in [5] and [3] estimate that, in the production of High Carbon Ferrochrome, up to 30-35% of the S and considerable quantity of P loaded in the furnace,will remain in the metal. All materials bring S and P in the furnace, but the main contributors are the coke for S and ore and coke for P.

The table 4 presents the results of calculations of the S and P balances for the first Quarter of 2016. The coke was calculated with 0.79% S, as the average of S in Bosnian (0.84%) and German (0.70%) coke. The Ferrochrome is calculated with the maximum S content that is required by the standard (0.10%) and with the actual average P content (0.027%).

Table 4. *Balance of S and P for 1-st Quarter 2016.*

Dry materials	Quantity, ton	S		P	
		%	Ton	%	ton
Ores	22622	0.005	1.13	0.004	0.90
Coke	3713	0.79	29.33	0.024	0.89
Quartz	3493	0.01	0.35	0.012	0.42
Total	29828		30.81		2.21
Ferrochrome	8126	0.10	8.13	0.027	2.19

S remaining in Ferrochrome = 8.13: 30.81 x 100 = 26.4% of loaded S (match with literature data). P remaining in Ferrochrome = 2.19: 2.21 x 100 ≈ 100% of loaded P (match with literature data). By performing the same calculations, we prove that for obtaining not more than 0.05% S remaining in Ferrochrome, so for producing Ferrochrome with low S content (ideally priced with higher sales), for example the mark FeCr70C70LS, the plant must use the coke containing not more than 0.40% S. Also, for obtaining not more than 0.075% S remaining in Ferrochrome (half of the range from 0.05 to 0.10% S), the plant must use the coke containing not more than 0.60% S.

In fact, during the first Quarter of 2016, there is no scarcity of Ferrochrome due to deviations of S and P, to bring out the standard output. On the other hand, there is very few casts with C content lower than 6%, but it can be marked in a group below, with 4-6% C. But by taking into account the interest for much higher sale prices, we present in table 5 the number of Ferrochrome casts with deviations of S and P from more positive values, but being within the minimum standard norms.

Table 5. *Ferrochrome casts vith deviations of S, P.*

%S, %P	January 2016		February 2016	
	casts/total of casts	%	casts/total of casts	%
0.05% ≤ S ≤ 0.10%	80 / 186	43	81 / 174	47
0.03% ≤ P ≤ 0.05%	- / 186	-	- / 174	-
%S, %P	March 2016		1-st Quart. 2016	
	casts/total of casts	%	casts/total of casts	%
0.05% ≤ S ≤ 0.10%	123 / 186	66	284 / 546	52
0.03% ≤ P ≤ 0.05%	34 / 186	18	34 / 546	6

So during the first Quarter of 2016 there were a total of 52% of production with 0.05% ≤ S ≤ 0.10% and 6% of production with 0.03% ≤ P ≤ 0.05%.

3.5. Coke

The experience of foreign specialists according to [5] and [3] and the experience of Albanian specialists lead us towards choosing the coke quality for the production of Ferrochrome, looking for suitable properties for:

- reactivity, reducing ability to load oxides,
- chemical composition (% of C, S, P, volatile compounds, humidity),
- sizing, porosity and density,
- quantity and chemical composition of Ash (irreducible oxides),
- mechanical resistance,
- electrical resistance.

3.6. Slag and Impact on the Degree of Desulphurization

According to [3], the basic slags improve the reduction of Cr_2O_3, increase Cr Recovery, improve the desulfuration and favor the production of Low Silicon Ferrochrome, but on the other hand reduce the electrical resistance of the load in the furnace, which negatively affects operating conditions and Electricity consumption. But the acid slags alsoi mprove the reduction of Cr_2O_3 and the Cr Recovery, but negatively affect the viscosity of slag, the separation of slag from the metal and the refractories consumption. There is in the slag a metal amount from 1 to 4% of the total amount of metal poured from the furnace.So the High Carbon Ferrochrome production process allows basic slags and acid slags as well, although theoretically the chemical nature of slag and its basicity contains some contradictions. In these conditions, every manufacturer must determine the appropriate nature of the slag to optimize its properties for the benefit of maximizing production indicators. An average chemical composition of the slag according to [1] is as follows:

Table 6. *Average chemical composition of slag in Elbasan Plant.*

SiO_2	MgO	Al_2O_3	CrO
42.9%	34.4%	9.25%	3.88%

The ratio MgO / SiO_2 = 0.80. So the slag is acidic. The reduction of the negative effects of the high content of MgO in Albanian ores and of the high ratio MgO / Al_2O_3, increasing the temperature of melting and the viscosity of slag, is realized increasingsignificantly the % of SiO_2 in the slag through a big quantity of Quartz, with a consumption nearly equal to that of coke.

The main compounds of slag are SiO_2, MgO and Al_2O_3 with a sum of 86.55%. Under the hypothesis that this sum would be 100%, it would be a ternary system with 49.5% SiO_2, 39.8% MgO,10.7% Al_2O_3 and according to the phase diagram MgO– SiO_2– Al_2O_3 [8], the melting temperature of slag would be at around 1650°C, as completely appropriate temperature for the process.

According to chemical tests of slags during the first Quarter 2016 [1] it is estimated an amount of 3–3.17% Cr in the slag, which represents about 5% of the amount of Ferrochrome poured from the furnace, an amount higher than that given by [3], wherein the amount of metal that is lost with the slag is 1-4% of the amount of metal poured from the furnace. Although this loss may be acceptable for acid slag, efforts can be made in future to reduce it, even through a post treatment of the slag.

However, we think that the indicators of the process with this slag have been positive in general, but we note that this positive situation is also favored by other important factors such as two separate tap holes for slag and for metal, the optimal electric regime and the appropriate fluidity of slag.

3.7. About the Goal for Cost Reduction

The goal of reducing the cost of production is important for the profitability of the plant, especially in the current international unfavorable prices of Ferrochrome. The possibilities for cost reduction are the most varied. They relate to:

- improvement of raw materials choice in terms of the ratio quality / price,
- improvement of metallurgical and energy efficiency,
- reduction the specific consumptions of raw materials, increase the amount of the finished product and improve its quality,
- reduction the technological losses,
- granulation the slag and sell it in granulated form for secondary purposes,
- ensurement a good electro-mechanical maintenance,
- improvement of the overall management level, etc.

The following table 7 presents a summary of key factual indicators of Elbasan Plant during first Quarter 2016 [9], [10], discussion of which helps to determine some specific targets for cost reduction.

Table 7. *Main technological parameters, during first Quarter 2016.*

Months	Kwh/T FeCr	kg ore/T FeCr	kg Coke/T FeCr	kg Quartz/TFeCr	R_{Cr}, %	Ton FeCr	% Cr inFeCr	% Cr_2O_3 in ore
Jan.	4220	2773	443	430	92.6	2760	68.80	39.20
Feb.	4370	2814	450	430	92.7	2572	69.16	38.68
Mar.	4340	2767	478	430	92.5	2794	68.88	39.30
1st Quarter 2016	4309	2785	457	430	92.5	8126	68.90	39.07

Specific Electricity consumption (about 27% of the overall cost) is at good levels. The expenses for this item can be reduced with future installation of a new transformer 12.5 MVA, construction of a new substation, etc. Specific Ore consumption (about 39% of the overall cost) fluctuates in wide limits, in function of many factors, some of which do not depend from the work of the plant. The possibilities for reducing the cost, depending from the work of the plant, are the strict control of chemical and granulometric composition of ores, the briquetting of entire amount of fines, the experimentation and initiation of briquettes from the chrome concentrates. Specific Coke consumption (about 15% of the overall cost) depends largely on its quality (reactivity, electrical resistivity and mechanical stability, content of C, S, P, Ash and moisture). Regarding the Quartz (Albanian origine) there is no interest for special measures, because its impact in the cost is insignificant (low buying prices).

3.8. Management

About the general management there is always place for improvement, regarding the tracking and qualitative identifying of the production to stabilize the growth to projected capacity levels, and consequently to increase the revenues and to reduce the costs. Besides the current duties for strict control and record of the quality of raw materials and finished products, it may be positive to be prepared for the certification of Elbasan Ferrochrome Plant under the standard ISO 9001 "Quality Management System - Requirements" [6], [7], as good practice for the sustainable improvements, servicing the quality and enhancing the image of enterprises, but especially of exporting ones.

4. Conclusions

Reconstruction of the furnaces in the Elbasan Plant, performed by "AlbCHROME", has been effective and has produced a significant progress compared to the period of operation of the "ACR", in terms of increasing the quantity and quality of the finished product, lowering costs and increasing revenue. The main improvement in the technology changes are the building of new construction with two tap holes for the metal and the slag and the optimization of slag formation process as well.

Chrome Recovery, during the period January – March 2016 was at good levels (92.5%). However, there is possible to improve it up to the level of 93%.

The chemical composition of Ferrochrome has been in good levels for Cr, C and Si, but the plant may undertake more efforts to achieve the best figures of the Standard ISO 5448 for the content of S and P.

The slag formation process has been positive, favored also by important factors like two tap holes, optimal electric regime and good fluidity of slag.

The Electricity consumption, as the key factor of energy efficiency, is at good levels and it is possible to stabilize its level at 4300 kWh/Ton Fe-Cr.

The Ore consumption can be reduced through rigorous control of chemical and granulometric composition of ores, briquetting of entire quantity of fines, experimentation and initiation of briquetting from the chrome concentrates.

The plant should be supplied with coke of higher quality than in recent months, regarding good levels of reactivity, electrical resistance and mechanical sustainability, with Sulfur no more than 0.6 – 0.7%, Phosphorus no more than 0.025%, Ash no more than 11% and Moisture not above 11%. Under these conditions, it is possible to stabilize the Coke consumptionat 450 kg/Ton Fe-Cr.

The certification of Elbasan Plant under the standard ISO 9001:2015"Quality Management System - Requirements" would be an important action to improve the management, promote the image of the Company and increase the confidence of clients, who import Albanian ferrochrome.

References

[1] Internal documentation of AlbCHROME – confidential information, (2016), Elbasan, Albania.

[2] International Standard ISO 5448: 1981 "Ferrochromium – Specification and conditions of delivery".

[3] M. GASIK: "Handbook of Ferroalloys – Theory and Technology" (2013), Elsevier, UK.

[4] SRK CONSULTING: "An Independent Engineers's Report on the AlbCHROME operations", (2014), UK.

[5] F. HABASHI: "Handbook of Extractive Metallurgy" (1997), Wiley-VCH, Canada.

[6] International Standard ISO 9001: 2015 "Quality Management System - Requirements".

[7] A. DHIMA: "Vlerësimidhe Menaxhimi i Projekteve" (2010), Pegi, Tirana, Albania.

[8] A. DHIMA: "Bazat e Metalurgjisë Ekstraktive" (2010), Pegi, Tirana, Albania.

[9] "Monthly Management Review" (February 2016), AlbCHROME, Elbasan, Albania.

[10] "Monthly Management Review" (March 2016), AlbCHROME, Elbasan, Albania.