

FERRO CHROME PRODUCTION IN ALBANIA

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ABSTRACT

In the year 2007 the smelting plant at Elbasan/Albania was stepwise revamped and the first submerged arc furnace for the production of ferro chrome high carbon was started up in 2008. After various technical modifications and relining also the second submerged arc furnace for the production of FeCr high carbon was successfully commissioned in August 2010.

The paper describes the revamping of the furnaces, the modification of the hydraulic system, the operation method with a modified tapping system and also the auxiliary equipment such as the laboratory, the slag handling and so on. Raw material selection and supply will be outlined and the achievements with regard to material consumption figures and product quality will be presented.

KEYWORDS: Pyrometallurgy, ferro chrome, smelting, FeCr production, Albania.

1. INTRODUCTION

Electric submerged arc furnaces (figure 1) are the state-of-the-art technology for the production of ferro alloys such as ferro chrome from oxidic ores [1].

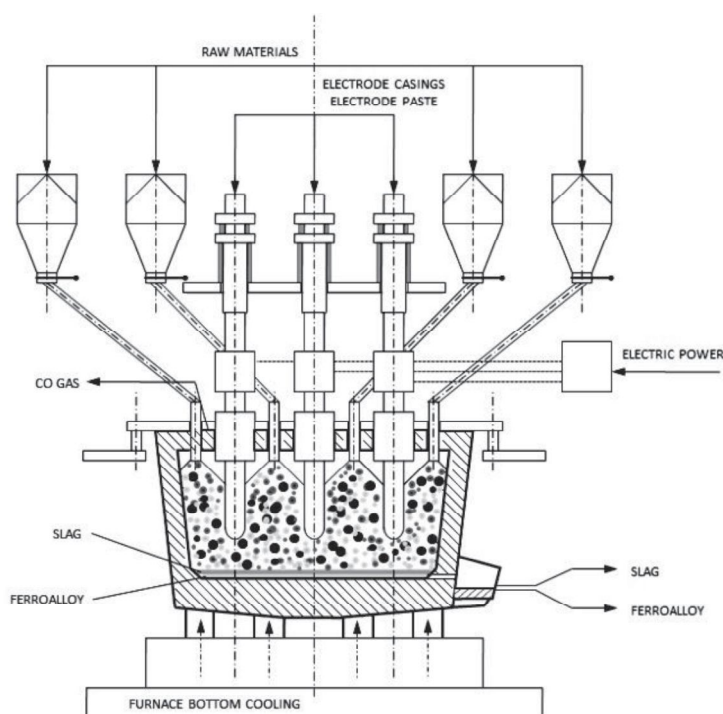


Figure 1: Electric submerged arc furnace, schematic view [1]

In most cases electric energy is transferred to the process via self baking carbon electrodes. The electrodes are laterally covered by the lumpy burden which has a higher electric resistivity than the molten bath below the electrode tips. Therefore it is granted that the electric current flows to the hot reaction zone.

The reaction zone itself (figure 2) consists of coke particles, molten slag and molten ore [2]. The real power input P depends on the electric current I , flowing through the electrodes, and on the electric heating resistance R in the reaction zone

$$P = I^2 \times R$$

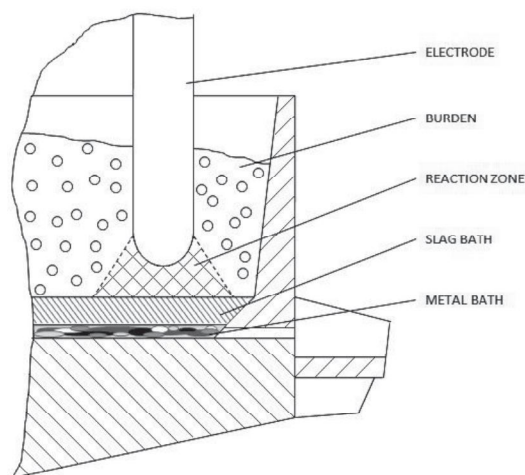


Figure 2: Reaction zone in the submerged arc furnance [1]

The resistance heating is a combination of the single resistances between the particles in the reaction zone, wheras also arcing occurs between the particles itself and the bath.

The burden consists of lumpy ore and/or agglomerated fine ores, slag forming agents and a source of carbon, in most cases coke or a blend of coke and semi-coke. The burden moves slowly down to the reaction zone, depending on the productivity of the furnace, and gets preheated on its way (in case of cold charging). While entering into the reaction zone the oxides with the lowest melting point are liquified first. Reaching the zone below the electrode tips finally all oxides are molten and the carbothermic reduction can take place with the solid coke particles, according to the equation



The remaining slag contains oxides with higher melting temperatures such as SiO_2 , Al_2O_3 , CaO and MgO . This slag forms a liquid layer on top of the liquid metal. Droplets of liquid metal descend through this layer and collect at the bottom of the furnace.

A decisive importance lays in the influence of the coke particles (quantity and size) on the electric resistance in the reaction zone and in the burden column. Therefore the coke has a double function, for the smelting reaction and for the conversion of electric energy into thermal energy. And it helps also to keep the burden permeable for the ascending CO gas.

The formation of carbides in the carbothermic reduction of ferro chrome starts already at low temperatures. Slag temperatures of up to 1650 °C always result in carbon contents of 7 to 8% in the FeCr. Only if the MgO-content of the ore is high and the slag temperatures exceed 1700°C the

carbon content will be between 4 - 6%. Lower carbon levels cannot be reached in the submerged arc furnace, a second process step would be required.

There are closed and open submerged arc furnaces. Closed furnaces offer the opportunity to collect the CO-rich off gas for preheating and partial pre-reduction of the burden, which results in a significant reduction of the electric energy consumption (figure 3).

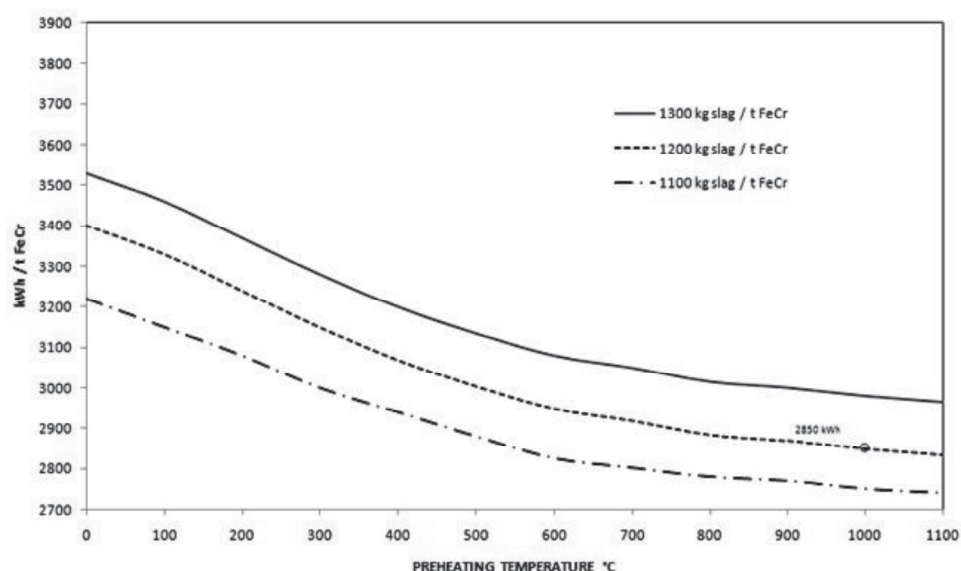


Figure 3: Influence of preheating temperature on the electric energy consumption when producing ferro chrome in the electric submerged arc furnace [1]

On the other hand the operation of a closed furnace demands more care in the burden preparation for a smooth production [3]. A typical scheme of a ferro chrome production with preheating is shown in figure 4.

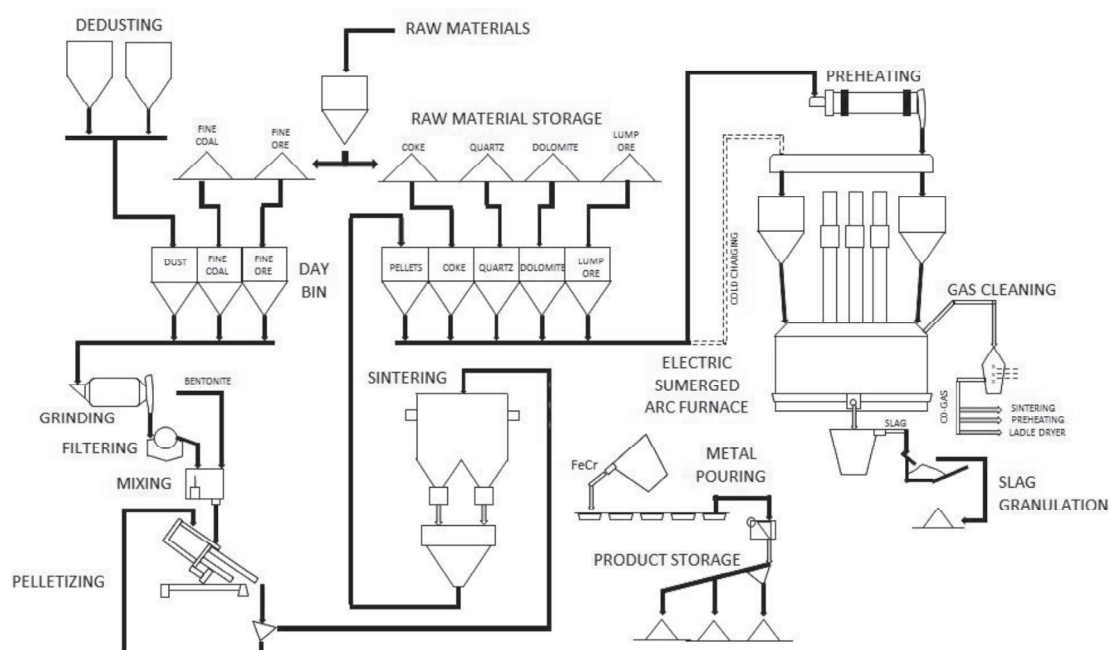


Figure 4: Basic process flow diagram of a ferro chrome plant [1]

Today selfbaking electrodes or Soederberg electrodes are commonly in use. For the reduction of the specific consumption figures bigger furnaces are of advantage, whereas a limit is reached at 100 MVA transformer rating and an electrode diameter of 2 meters [4]. The electrode consumption also depends on the electrode diameter. In the case of large electrode diameters the attention must be on the slipping speed and the baking rate, which in the worst case may lead to green paste breakage.

2. TECHNICAL/TECHNOLOGICAL MODIFICATIONS OF THE ELBASAN SMELTING

1.1. Furnaces for production of FeCr HC

When ACR took over the Elbasan FeCr HC smelting plant from Darfo, the production capacities of this plant consisted of two submerged arc furnaces, open type, with respective transformers of 9 MVA and an electrode diameter of 900 mm. These furnaces had two tap holes, one for slag and one for metal. The tap holes were placed at 90° from each other and the slag tap hole was 600 mm higher than the metal tap hole. ACR modified the furnace's metallic shell and consequently the furnace lining to one tap hole (closing the slag tap hole).

Modifications were due to the casting bay area to cope with one tap hole furnace operation. This technical modification required a new tapping schedule. As the result of this, the process was intensified and therefore the production increased by approx. 10%. Another technological modification was the slag property. From 2002 till 2007 Darfo operated the furnaces by adding fluxes (quartzite) to create an acid slag (SiO_2 content in the slag between 40 - 42% and $\text{MgO} = 34 - 36\%$) while when ACR started the first furnace in 2008 (furnace No.3) the slag of the smelting process was basic (SiO_2 content in the slag is in the range of 33 - 35% and $\text{MgO} = 38 - 40\%$). This technological change improved also the energy consumption by attaining a lower melting point of the slag [5]. The actual specific energy consumption of smelted FeCr is 3.9 - 4.0 MWh/ton.

The refurbishment and reconstruction of the furnace № 2 which started in May 2010 and ended by the end of August of the same year affected the electrode clamp system and the refractory lining of the furnace.

The electrode clamps before the modifications were held and pressed by a system using oil as pressurizing medium. The new system was changed to water glycol as pressurizing system. Water glycol, assuring the same hydraulic mechanical/physical quality as oil is safer when it comes in contact with equipment under high temperatures.

The relining of the furnace No. 2 was done with magnesite bricks (bottom and hearth zone), while the furnace walls were lined with chamotte and alumina bricks (figure 5). Besides the changes of the refractory materials quality, the configuration of the furnace lining was modified (aiming to improve it) by making the furnace bottom spherical instead of flat according to the previous design. Spherical shape of the furnace bottom gives a better stability of the brick works at this area and prevents brick floating during operation of the furnace while bricks of the bottom start to wear out.

The relining of the furnace No. 3, which was finished in April 2012, followed the same concept like at furnace No. 2.

1.2. Raw material

It is understandable that chemical and physical properties of the raw material are crucial for the technological process of the submerged arc furnaces for production of FeCr HC. Raw material for Elbasan plant is assured by: Bulqiza mine (ACR's own mine) providing up to 25% of the plant

ore needs. The quality of the ore coming from Bulqiza is one of the best among the other ore producers. Table 1 shows the chemical composition of the Bulqiza ore:

Table 1: Chemical composition of Bulqiza ore

Component	Content
Cr ₂ O ₃	42 - 44 %
Fe ₂ O ₃	12 - 14 %
MgO	22 - 24 %
SiO ₂	8 - 10 %
Al ₂ O ₃	6 - 8 %

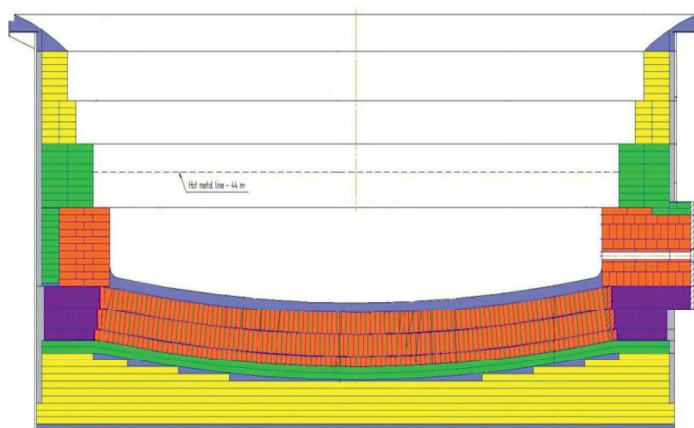


Figure 5: Refractory lining of the submerged arc furnaces

The composition of the Bulqiza ore shows that this ore contains a relatively high MgO content while the Al₂O₃ content is low. The ratio MgO/Al₂O₃ being at the range of 3 is not suitable for the smelting process, this especially related with the slag properties. Such a slag is highly viscous, tapping is difficult and the physical losses of FeCr are high (a viscous slag makes it difficult for the FeCr droplets to settle down).

To decrease this ratio ore from South Africa was used having both, low MgO and high Al₂O₃ content [6]. Recently, to lower the production costs, crushed pieces of used chamotte bricks were used as flux to bring Al₂O₃ up in order to achieve a MgO/Al₂O₃ ratio of 2.0 - 2.2.

The majority of the ore quantity for the Elbasan plant (75% of the ore needs) comes from third party ore suppliers. The mineralogical structure of the ore from third parties is in general the same as the one from Bulqiza as most of the chrome ore producers operate in the same area but their quality is poorer. The quality of ore coming from third parties is shown below:

Table 2: Typical chemical composition of third party ore

Component	Content
Cr ₂ O ₃	38 - 42 %
Fe ₂ O ₃	12 - 14 %
MgO	24 - 26 %
SiO ₂	10 - 14 %
Al ₂ O ₃	6 - 8 %

There are a few small mines in the south-east and north-east of Albania which have a slightly different chemical/mineralogical composition. The chrome ores from the south-east part of Albania, being close to iron ore deposits, have a low Cr/Fe ratio of 2.5 - 2.8. Supplies from these mines are sporadic and these ores have always been used together with the ores from the Bulqiza region, being the basis of the ore blending for furnace burden.

The open furnaces are known to tolerate quite some ore fines in the charge, up to 30%. However the fines content in the used raw material is an issue. While the lumpy ore coming from ACR's Bulqiza mine has a good sizing, the ore from third parties has 20 - 30% of fines as delivered and after crushing of course twice as much. Being in an situation when it was difficult to manage the smelting process due to very high fines content in the feeding material, sometimes the ores had to be screened before charging them into the furnaces.

For an average of 40 - 42% Cr₂O₃ content in the blended ore of the charge and a Cr/Fe ratio of 3.0 - 3.2, the specific ore consumption per ton FeCr min. 65% is 2.7 - 2.9 tons.

2. QUALITY CONTROL OF RAW MATERIALS AND FINAL PRODUCT

When ACR took over the Elbasan plant, the plant laboratory was equipped with an old carbon and sulphur LECO analyzer and a 20 years old atomic absorption spectrometer (AAS) VARIAN. The AAS requires a sample preparation by wet chemistry leading to 6 - 8 hours of time to get the result. With this method/equipment, it was not possible to do the operative analysis to manage and monitor the process so only the analyses of ore and final product (FeCr) were executed.

The process was managed by only knowing the carbon and sulphur which was analyzed by LECO CS analyzer.

ACR upgraded the plant laboratory by adding another computerized LECO 230 CS analyzer which was much more accurate and reliable. But the main change regarding the analysis quality and possibility to control the technological process came with the installation of the X-Ray fluorescent spectrometer AXIOS produced by PanAnalytical.

This powerful machine allows the lab to provide analysis results of all raw materials, by product (slag) and final product (FeCr) with a range (but not limited) of 20 chemical elements in half an hour, (sample preparation included). With this X-RF instrument, the smelting process is followed and guided closely every shift by knowing not only carbon and sulphur content in the alloy but also by knowing the analysis of slag, coke, ores and fluxes added into the furnace.

The result of such meticulous smelting process monitoring was of course a smoother operation of the process and a guaranteed product quality. The achieved Cr₂O₃ content in the slag was in the range of 3 - 4%. The product FeCr HC is without doubt one of the best ferro chrome high carbon in the market. Below the product specification of Elbasan's FeCr HC is shown:

Table 3: Product specification of ACR FeCr HC:

Element	Limit Value
Cr	min. 65 %
C	max. 8.0 %
Si	max. 1.0 %
S	max 0.05 %
P	max 0.03 %

3. BY PRODUCT (DUST, SLAG) AND FINAL PRODUCT (FE Cr) TREATMENT

3.1. Off gas

As mentioned above, the Elbasan submerged arc furnaces are of open type. The CO produced by the reduction reaction taking place in the furnace, once in contact with the ambient air reacts to CO₂. So the off gas coming out of the furnaces contains mainly CO₂ and very little CO. The off gases via two pipes situated on the furnace hood are conducted to the off gas ducts which lead the gases to the bag filter. The dust is caught by filter bags, and after being briquetted it is fed back to the smelting furnaces. The cleaned off gases are discharged into the atmosphere.

3.2. Slag

The slag coming out of the smelting process, though it contains a relatively low Cr in form of Cr₂O₃ contains inevitably metallic FeCr. The metallic FeCr in form of “trapped” droplets is incorporated inside of the solidified slag. The slag of the process is sent to the slag treatment line where it is crushed and screened and the fractions rich of FeCr having magnetic properties are separated from the remaining slag by two magnetic separators. The magnetic fractions are returned back to the smelting furnaces while the poor slag is dumped to the slag deposit. Magnetic separation is not the most efficient way to recover the mechanical FeCr losses within the slag. However, the treated slag deposited in the dump area is kept to be probably retreated by a more sophisticated and efficient method in future.

3.3. FeCr HC

The liquid FeCr is cast in concrete moulds lined with fire resistant bricks and covered with FeCr fines 0-5 mm. The solidified FeCr ingot is then pre-crushed to lumps of 300 x 300 mm and sent to the crushing-screening line.

Depending on the customer's demand the screens are set up to produce the required sizing. Mostly, the final product sizing is 10–50 mm and 50–80 mm.

4. SUMMARY

Albanian Chrome (ACR) has achieved a significant improvement in productivity from formerly 30 t/day to 50 t/day. This is especially remarkable taking into account the comparably small furnace size and the ore with a relative high MgO content. Results like 2.7 to 2.9 t of ore per ton of ferro chrome and 3 000 to 4 000 kWh/t FeCr can be considered as excellent.

5. REFERENCES

- [1] Glöckler G. and Müller H.G., “A Comparison of the Electric Submerged Arc Furnace and the Plasma Smelting Furnace”, BHM, 134. Jg. 1989.
- [2] Hayes P.C., “Aspects of SAF smelting of ferrochrome”, Pyrosearch, Pyrometallurgy Research Centre, Queensland, Australia INFACON X: “Transformation through Technology”, 2004.
- [3] McCullough S., Hockaday S., Johnson C. and Barcza N.A., “Pre-reduction and smelting characteristics of Kazakhstan ore samples”, The Twelfth International Ferroalloys Congress, Helsinki, Finland, 2010.
- [4] Daavittila J., Honkaniemi M. and Jokinen P., “The transformation of ferrochromium smelting technologies during the last decades”, Outokumpu Technology Oy, Espoo, Finland,

- INFACON X: “Transformation through Technology”, 2004.
- [5] Farjadi M.H. and Azari J., “Effect of chrome ore quality on ferrochrome production efficiency, Faryab Mining Company. Tehran, Iran, INFACON X: “Transformation through Technology”, 2004.
- [6] Chirasha J. edited by: Jones R.T. and den Hoed P., “Ferrochrome smelting and smelting capacity investment in Zimbabwe”, Zimbabwe Alloys Chrome, Gweru, Zimbabwe, Southern African Pyrometallurgy, Southern African Institute of Mining and Metallurgy, Johannesburg, 2011.