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# Technology Innovations in the Smelting of Chromite Ore

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**Abstract**

The increasing costs of electric energy and thus the need to reduce the energy required to produce ferrochrome from chromite ore have spurred the innovations in the technologies used for smelting chromite ore. These technologies (Conventional smelting process, Outokumpu process, DC arc route, and Premus process) have been reviewed in this work. Premus process has been found to be the lowest-cost and most energy-efficient ferrochrome smelting technology. The process is designed to reduce electrical energy consumption during smelting by partly reducing pelletized chromite ores in a rotary kiln using energy obtained from coal pulverization and hot gases generated from the closed submerged arc furnace. It also provides high recoveries of ferrochrome and utilizes low cost reductant sources such as anthracite.

**Keywords:** Chromite ore, Ferrochrome, Submerged arc furnace, Outokumpo, Premuse

## 1. Introduction

The mineral chromite, with chemical composition $FeCr_2O_4$ (ferrous chromic oxide), is a sub-metallic mineral belonging to the spinel group (with a generic formula of $R^{+2}O.R^{+3}O_4$). It is the only economic mineral mined for chromium, a steel-gray, radiant, hard metal used mainly for making stainless steel. Because of the high heat stability of chromite, it can also be used as a refractory material for high temperature vessels such as furnaces.

Two main products can be achieved from the refining of chromite namely: ferrochromium and metallic chromium. Smelting operation must be carried out on the chromite ore in order to refine it into any of the two products mentioned above. One of the major problems encountered during chromite smelting is the issue of energy or electricity. Large amount of energy is required to smelt chromite to produce ferrochromium or metallic chromium. According to Keesara (2009), up to 4,000 KWh of energy per ton material weight is required for smelting of chromite. This intensive energy is as a result of the high melting temperature of chromium.

In terms of minerals economics, the revenue generated from a ferrochromium plant is a function of Cr/Fe ratio (Buchanan, 2001). The higher the ratio, the higher the revenue the plant stands to make. However, with the increasing cost of electric energy, an economic chromite mine can become uneconomic if large amount of electric energy is required to smelt and refine the ore into ferrochrome. There is no point smelting a chromite ore if breakeven cannot be achieved. During chromite smelting, energy requirement and its cost depend to a large extent on the technology used in smelting the ore. New process technologies have been developed to reduce energy required for smelting chromite to ferrochrome. These technologies, together with the conventional chromite smelting technique, are what this paper aims to discuss.

## 2. Chromite Smelting Technologies

Four primary processes are available for smelting chromite ore to produce ferrochrome. They are: Conventional smelting process, Outokumpu process, DC Arc route, and Premus technology. These technologies are discussed below:

 

2.1 Conventional Smelting Process

The traditional chromite smelting technology involves charging the chromite ore into a submerged AC Electric Arc Furnace (Figure 1) and reductants (coke, coal and quartzite) added to reduce the ore into ferrochrome. The metal/ferrochrome and slag produced are tapped from the furnace for further processing. According to Naiker (2006), the primary advantages of the conventional smelting process are low capital investment and flexibility in terms of raw materials that can be used in the process. However, in terms energy requirement, the process is not efficient as it is an energy intensive process, requiring up to 4,000 KWh per ton material weight (Figure 2a). Figure 2b shows the indexed energy cost per ton of alloy. The conventional smelting process requires about 1.0 indexed energy cost per ton of every ferrochrome alloy produced.

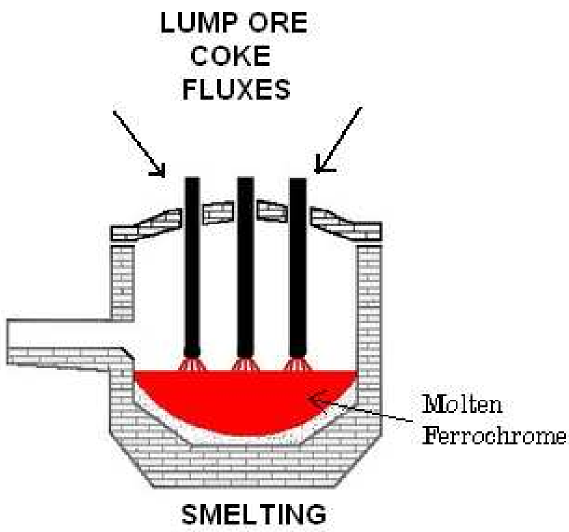


Figure 1 Schematic illustration conventional smelting using submerged EAF (The Full Wiki, 2012)

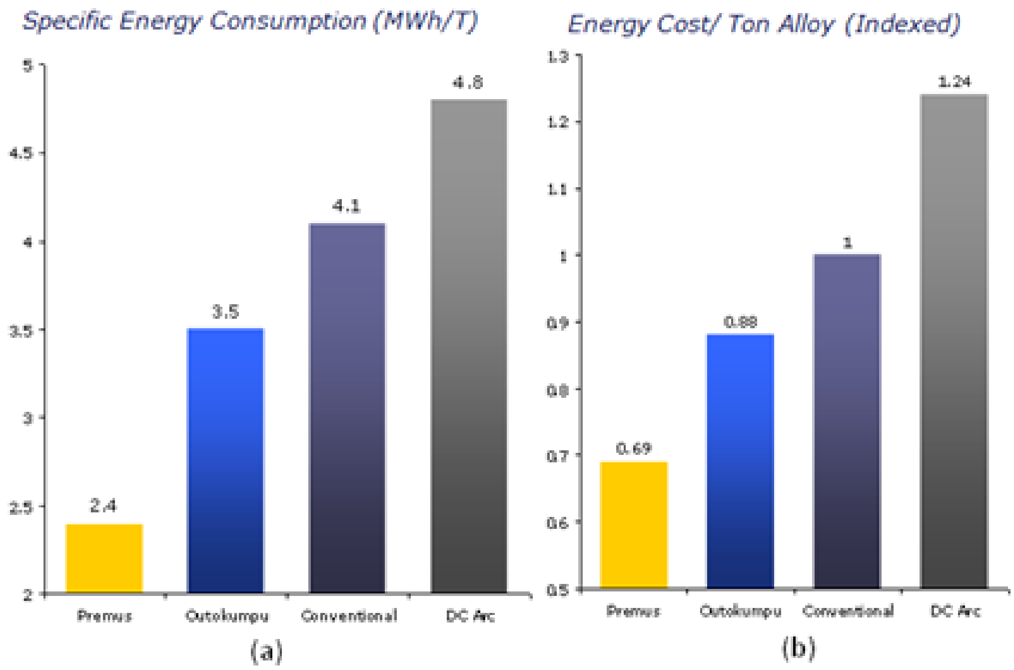


Figure 2 Energy consumption comparison chart (Lion Ferrochromiun, 2009)

2.2 Outokumpu Process

Outokumpu process involves grinding and pelletizing of ore fines, followed by sintering of green pellets and preheating before smelting (Rao and Singh, 1996; Goel, 1997). According to Goel (1997), the ore and coke fines are normally wet-ground to about 35 percent under 37 micron (400 mesh) and then pelletized to approximately +15 mm size. Figure 3 shows the flowsheet of Outokumpu process. As it can be seen in Figure 3, the preheating operation is done mainly in a rotary kiln and the energy required for sintering and preheating the pellets comes from the CO gas generated from the submerged arc furnace. In Outokumpu process, the chromite ore is partly reduced in the rotary kiln during preheating, thereby reducing the amount of electric energy required for final smelting of the ore to ferrochrome. Therefore the technology when compared to that of the conventional smelting process saves energy (see Figures 2a and 2b).

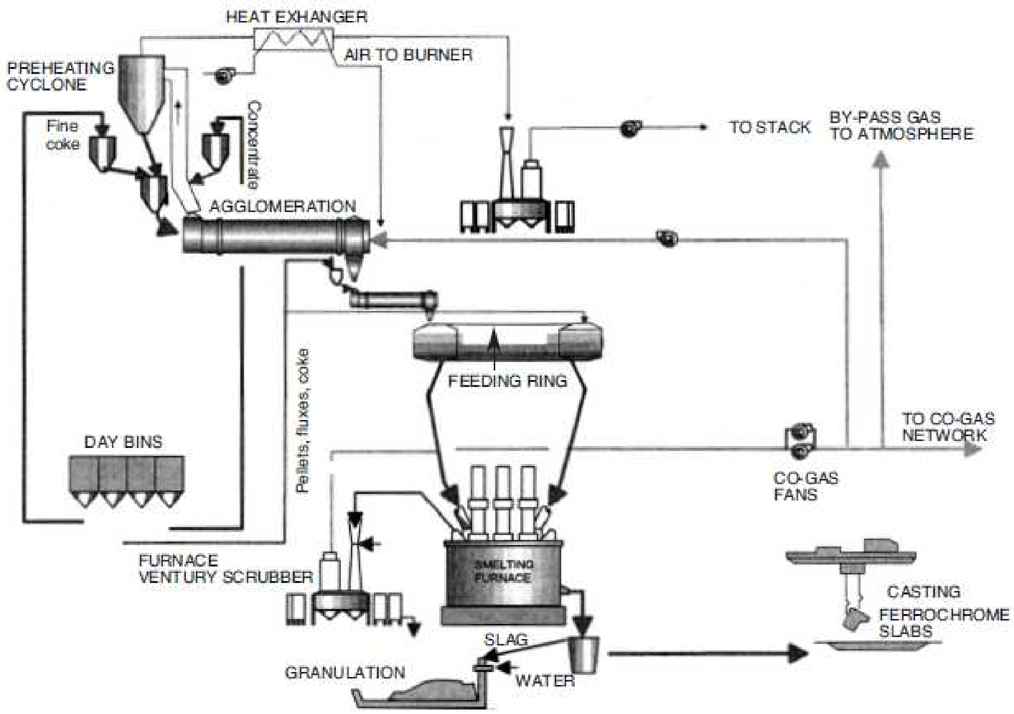


Figure 3 Outokumpu process (Daavittila et al., 2004)

2.3 Dc Arc Route

DC arc furnace uses a single solid carbon electrode as the cathode, and produces a DC arc to an anode in the bottom of the furnace (Figure 4). The arc is normally an open or semi-submerged one (Naiker, 2006). Raw materials can be charged either directly into the furnace, or by using a hollow electrode. The DC arc route was designed mainly to overcome the problem of ore fines encountered in conventional chromite smelting process. In terms of energy, the process consumes large amount of energy (Figures 2a and 2b) and therefore may render a chromite mine uneconomic. However, in terms of coke consumption, the technology has been designed to work without using coke as a reductant (Figure 5). Therefore to use this technology for producing ferrochrome, there is the need to reach a compromise between coke consumption and energy requirement.

2.4 Premus process

Premus process, Xstrata's proprietary technology in use at the Lion Ferrochrome plant in South Africa, is the most sophisticated, competitive and technological advanced process available for the production of ferrochrome from chromite ore (Xstrata, 2012). The technology involves three stages: sintering, pre-reduction, and smelting. Energy reduction, just as was observed in Outokumpu process, is achieved in the pre-reduction stage of the process. As it can be seen in Figure 6, the chromite pellets from the sintering stage are pre-reduced in a rotary kiln by roasting operation before being charged into the closed submerged arc furnace for final smelting. The pre-reduction process results to the reduction of energy required in the closed submerged arc furnace for final smelting of the ore into ferrochromium. It is worth noting that the energy used in the pre-reduction stage is obtained from the hot gas generated from the closed submerged arc furnance and also from coal pulverization, and thus is not paid for. With this technology, Lion Ferrochromium is now in the forefront of chromite smelting in South Africa.

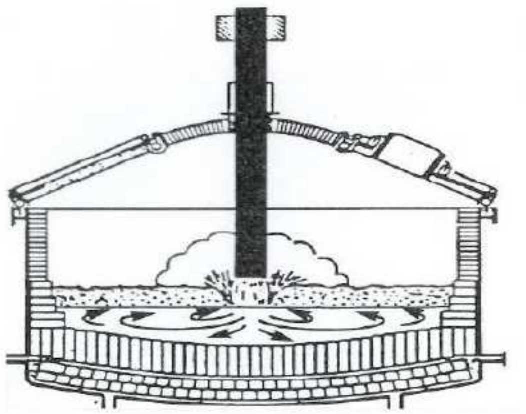

Figure 4 DC arc route process (Curr, 2009)

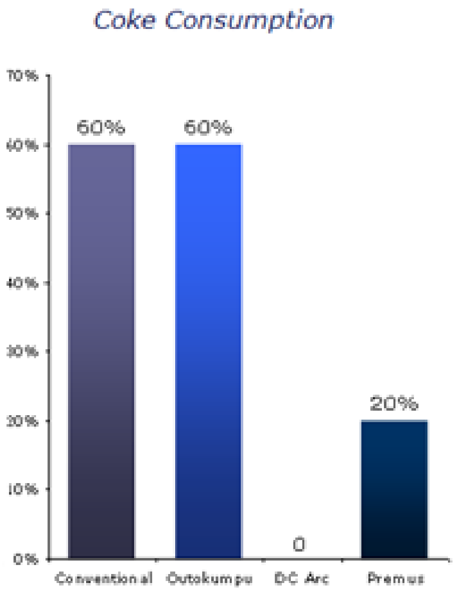


Figure 5 Coke consumption comparison chart (Lion Ferrochromiun, 2009)

As it can be seen in Figure 2a and Figure 2b, Premus technology is the lowest-cost and most energy-efficient ferrochrome technology. The technology also uses low cost reductant material (anthracite) and thus as can be seen in Figure 5, coke consumption is low in Premus technology.

Another important feature of this technology, which is also a part of the DC arc route and Outokumpu process, is that it is designed for smelting fine chromite ores. The convectional smelting process is designed to handle only lumpy ores which are ideal for ferrochromium production as the fine ores tend to form a sintered layer at the top of the charge, preventing gas escape and thus causing operating difficulties (Buchanan, 2001). With this problem, it means that fine chromite ores are not of economic value. However, with the development of the Premus technology, DC arc route, and Outokumpu process, fine chromite ores can now be smelted as the technologies have been designed to convert the fine ores into pellets during the pre-reduction stage. These technologies can therefore be used to generate more revenues in localities having large amount of fine chromite ore.

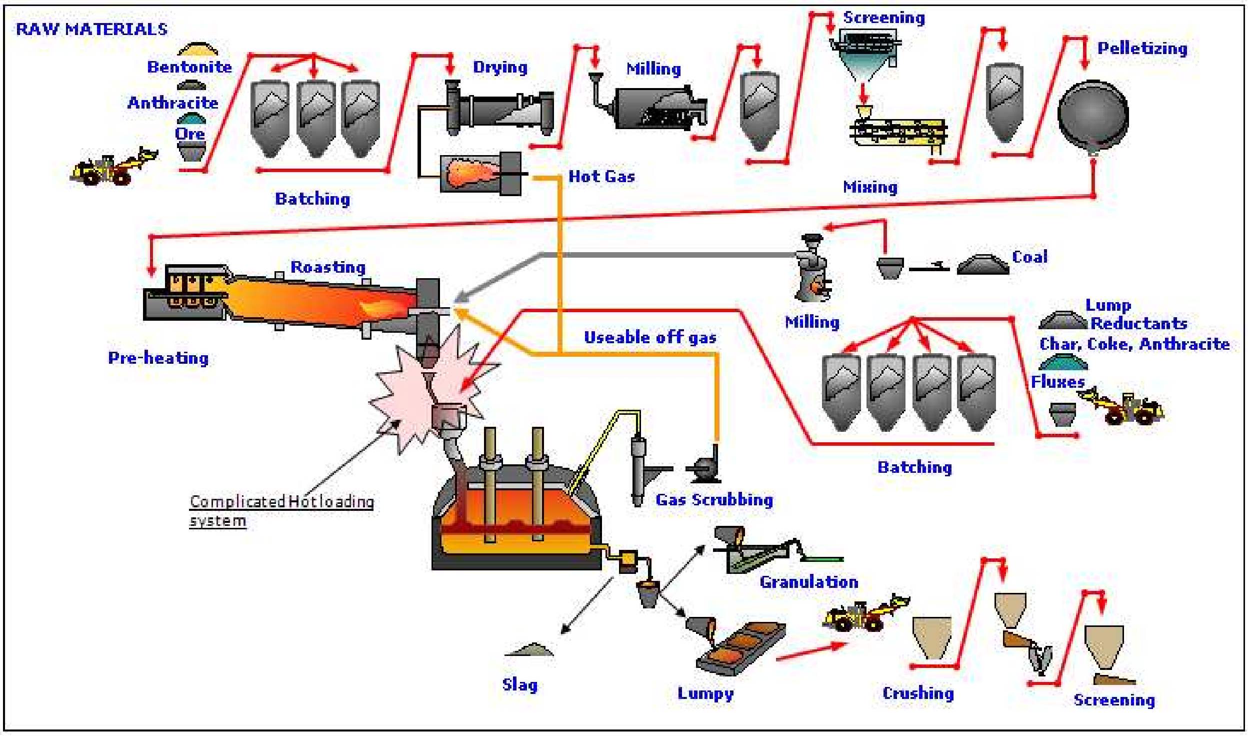


Figure 6 Schematic illustration of Premus technology (modified from Naiker, 2006)

## 3. Conclusion

The development in the technology used for smelting chromite ore to produce ferrochrome is as a result of the need to reduce chromite smelting energy in order to cushion the effect of increasing costs of electric energy. By partly reducing pelletized chromite ores in a rotary kiln using energy obtained from coal pulverization and hot gases generated from the closed submerged arc furnace, the electric energy required for chromite smelting is reduced. Out of the four primary technologies (Conventional smelting process, Outokumpu process, DC arc route, and Premus process), Premus process is the lowest-cost and most energy-efficient ferrochrome technology. The technology uses low cost reductant material (anthracite) for preheating chromite pellets.

Large amount of energy is required in the DC arc route process when compared to other technologies; however, in terms of coke consumption, the technology has been designed to work without using coke as a reductant. A compromise can be reached in terms of energy requirement and coke consumption, thereby making the process economic for chromite ore smelting.

During smelting, fine chromite ores form a sintered layer at the top of the charge, preventing gas escape and therefore causing operating difficulties. However, with the development of Outokumpu, DC arc route, and Premus technologies, this problem is now a thing of the past as the technologies have been designed to handle fine ores. The fine ores are converted into pellets before smelting. Thus these technologies can be used to generate more revenues in localities having large amount of fine chromite ore.

**References**

Buchanan, D. L. (2001). Geological Setting of Nickel, Chromium and Vanadium Ore Deposits. In: Dunton, S. N. and Jones, M. J. (eds). The Institution of Mining and Metallurgy

Curr, T. R.(2009). The History of DC Arc Furnace Process Development. Retrieved from http://www.mintek.co.za/Mintek75/Proceedings/C01-Curr.pdf

Daavittila, J., Honkaniemi, M., and Jokinen, P. (2004). The Transformation of Ferrochromium Smelting Technologies during the Last Decades,SAIMM Proceedings of the Tenth International Ferroalloys Congress, pp. 541-549

Goel, R. P. (1997). Smelting Technologies for Ferrochromium Production – Recent Trends. NML, Jameshedpur – 831 007, pp. 37-50

Keesara, V. C. (2009). Chromite. Retrieved from http://www.scribd.com/doc/17277588/Chromite-Lion Ferrochromium Field Trip Presentation, South Africa

Naiker, O. (2006). The Development and Advantages of Xstrata's Premus Process. Retrieved from http://www.pyrometallurgy.co.za/InfaconXI/011.pdf

Rao, V. O. and Singh, B. K., (1996). Turn Around Story at Ferro Alloy Plant. Bamnipal, Tata Tech., Vol. 23, pp. 83-87

The Full Wiki (2012). Electri Arc Furnace: Wikis. Retrieved from http://www.thefullwiki.org/Electric_arc_furnace

Xstrata (2012).Lion Ferrochrome Smelter. Retrieved from

http://www.xstrataalloys.com/EN/Operations/Pages/LionFerrochromeSmelter.aspx