Ferrochrome Smelting in Zimbabwe

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Abstract

The Zimbabwean ferrochrome production sector is dominated by four main players, with ZIMASCO and ZimAlloys being biggest and oldest producers. The other two smaller producers are Maranatha Ferrochrome and Oliken Ferroalloys. Some small-scale smelters have recently opened up including MonaChrome, Wel Mining,CINA and Jin An Corp & Xinyu. Zimasco and Zimbabwe Alloys own the largest number of claims along the Great Dyke, the largest source of metallurgical grade chromite ore in the world. Zimbabwe is the only country that has both stratiform and podiform types of chrome ores that are exploitable for ferrochrome production. South African reserves mainly occur as stratiform deposits. However, the podiform ores are quickly running out, and attention has turned to utilization of the friable stratiform ores, which tend to be more friable and thus require pre-treatment prior to smelting in conventional submerged electric arc furnaces.

Although Zimbabwe has seen a significant number of new investment in chrome ore mining, there has been relatively limited investment into the ferrochrome smelting sector. Smelting capacity expansion has remained largely stagnant, relative to other minerals such as platinum and gold that have seen marked cash injections.

1. Introduction

Zimbabwe ferrochrome production is mainly from four smelters, namely ZIMASCO in Kwekwe, ZimAlloys in Gweru, Maranatha in Kadoma and Oliken in Kwekwe. However, new entrants to the market include some small-scale smelter installations exploiting Dyke ores, namely MonaChrome in Chegutu, CINA, Jin An Corp & Xinyu and Wel Mining all based in Gweru. Historically, ZIMASCO and ZimAlloys represent more than ninety per cent of Zimbabwe‘s ferrochrome smelting capacity, producing three ferrochrome products namely High Carbon Ferrochrome (HCFeCr), Ferrosilicon Chrome (FeSiCr) and Low Carbon Ferrochrome (LCFeCr). Ferrochrome smelting is a labour and energy intensive process. The principal application for chromium is as an alloying element in cast irons and steels. It is a strong carbide-forming element, and as such it is an important alloying element in tool and die steels, and high speed steels.

Zimbabwe currently has the capacity to produce about 490K tonnes per annum of ferrochromium alloy, which represents only about 6% of the world production and equivalent to about 16% of South Africa‘s production based on 2008 figures.

2. Smelting in Zimbabwe

The chrome industry, in general, consists of three value system components, which collectively describe the structure and dynamics of the industry;

a. Ore producers
   - The industry is segmented by ore characteristics:

    i. Refractory grade ore (>60% Cr),
    ii. Metallurgical grade ore (>46% Cr),
    iii. Chemical grade ore (40% < Cr < 46%)

b. Alloy Producers
    - Integrated alloy smelters,
    - Independent alloy smelters

c. End-use customers
    - Primary stainless producers
        i. Stainless steel,
        ii. Alloy steels,
        iii. Non-ferrous alloys,
        iv. Specialty Mills
    - Refractories and foundries,
    - Chemicals.

The chromium content of the alloy is a function of the chromium (Cr) and iron (Fe) contents of the ore, with the chromium to iron ratio being a key parameter; the higher the Cr/Fe ratio in the ore, the higher the Cr content in the resultant alloy.

3. Ferrochrome Smelting Process

3.1. Raw Materials

3.1.1. Chromite ore

Chromite ore is the only commercial source of chromium. About 80% of world production comes from India, Iran, Pakistan, Oman, Turkey and Southern Africa (which produces half of this).

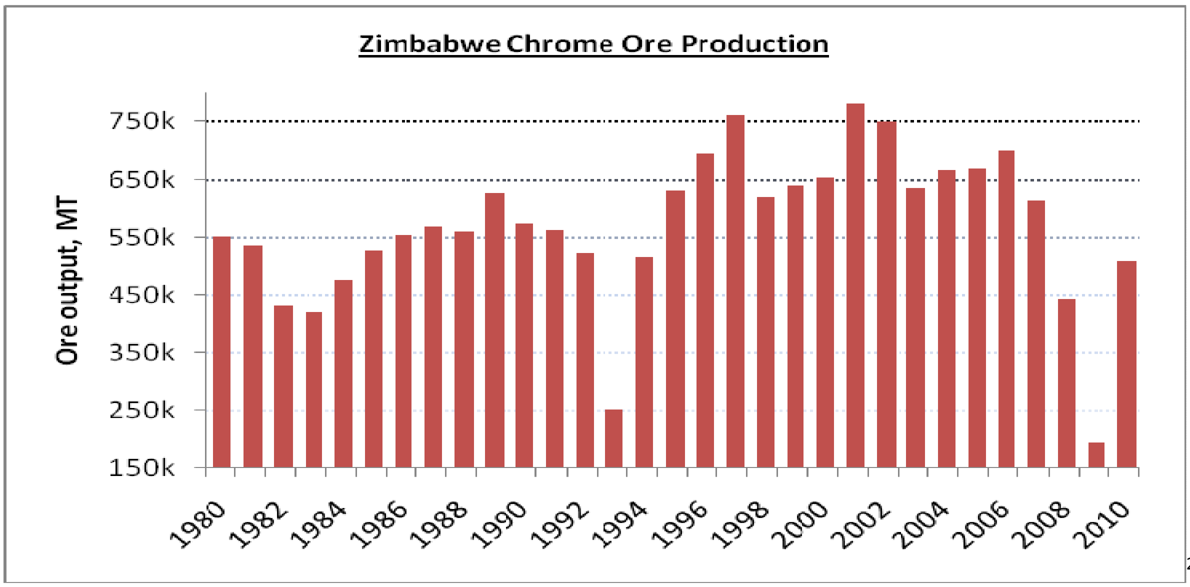
In Zimbabwe, chrome occurs in two distinct geological environments; the Great Dyke and the Greenstone belts. About 95% of chromium resources are geographically concentrated in southern Africa and Zimbabwe is estimated to host over 80% of the world's resources of metallurgical[1] quality chromite, mainly on the Great Dyke. By far, the largest deposits are contained in 11 narrow seams (stratiform) in the Great Dyke (approximately 550 km long and 11 km wide). Although the seams are narrow, averaging 10cm in thickness, they extend on both sides of the entire length of the Dyke. In addition to the seams, neighbouring rock formations contain disseminated chromite, which on weathering is concentrated into rich alluvial deposition on the flanks of the Dyke.

Greenstone belt deposits occur as pods and pipes in some ultramafic rocks of the Shurugwi and Mashava Greenstone belts, and ultramafic bodies in the Limpopo Mobile Belt in Mberengwa district. The Shurugwi deposit is one of the most important sources of metallurgical chromite in the world. These ore deposits are refractory and lumpy and are therefore perfect ferrochrome refiners. However, this type of ore is quickly depleting. Zimbabwe has total reserves of about 140 million tonnes with resources

[1] ICDA Chromium mining

of a further 1 billion tones, and is the only country in the world that has exploited both stratiform and podiform deposits.

Underground mining of stratiform deposits is most often required but can be particularly difficult due to the narrow seam thickness, weathering (close to surface) and faulting. Open-pit mining was generally applied to the podiform ores at first but this progressed to underground mining as deeper levels of the deposit were reached. Historically, there was sufficient high-grade metallurgical ore to meet demand but with the rapid growth of the stainless and other alloy steel industries, the much larger reserves of the lower Cr grade (low Cr/Fe ratio) ores have had to be exploited. Although there is a high demand for raw chrome ore on the international markets, particularly on the Chinese market, the country has generally adopted the policy not to export raw chrome ores.



[2]

Figure 1. Zimbabwe Chrome ore production

Podiform chromite ore reserves are expected to run out by 2015, and the smelting technology will have to evolve with more investment in the industry to enable efficient smelting of the more friable ores from the Great Dyke. Briquetting at Zimbabwe Alloys and block-making at ZIMASCO have been successfully implemented, improving yields and the extra benefit of consuming fines that would otherwise be unsuitable using current furnaces in operation.

Current advances world-wide are more focused on utilizing the fines and concentrates generated during the handling of the friable ores. The recovery of chromium is reduced by at least 8% if fines are used in the smelting operation. When the low cost fines are agglomerated to even-sized, hard and porous feed material in pelletising and sintering plants, their behavior in the furnace is even better than that of hard lumpy and the consumption of electric energy in smelting is reduced considerably.

[2] Mineral Production Statistics, Zimbabwe Chamber of Mines, 2010

3.1.2. Power

The current installed chrome smelting arc furnaces in Zimbabwe are high-energy consumers (averaging 3.8 to 4.0MW/MT FeCr). The trend elsewhere has been to build increasingly larger, more efficient units with higher power density per unit of hearth area (kW/m^2) to optimize the considerable capital investment required and the huge running costs associated with ferrochrome production. These units are usually closed or semi-closed in order to utilise the energy in the off-gas both directly and indirectly. The escalation of energy costs has stimulated the development and implementation of new technology that has dramatically reduced furnace power consumption. Investment cost of the smelting furnaces does not increase linearly with the active power. Instead, the extra cost/MW decreases as the furnace size increases[3]. The two major producers of ferrochrome in Zimbabwe have announced plans to increase their capacities, with ZIMASCO replacing the No 2 furnace with a bigger semi-closed unit and Zimbabwe Alloys are set to upgrade their three arc furnaces and construct a DC arc furnace in the near future. By way of comparison, the size of the smelting units used in ferrochrome production outside Zimbabwe has increased during the past 40 years 6 – 7 times, from 10 MVA to at least 65 MVA.

4. Ferrochrome Smelting Challenges

The challenges of current ferrochrome production are reduction of investment and operating costs (CAPEX & OPEX), minimizing waste and improvement of the SHE performance of the processes. The long-term global trend of ferroalloy prices, in general, is downwards, as a result putting a lot of pressure on producers to reduce overall production costs in order to maintain viability of the industry.

Zimbabwe’s advantage over other players, notably the hard lumpy ore, is quickly depleting, and consequently considerable attention is being paid to processing of the fines and concentrates generated during weathering or handling of the friable ore.

The efficiency of the ferrochrome process is very much driven by the type and pre-conditioning of the feed materials. Processing fine feed material requires high operating temperatures and consequently high power input to ensure the even flow of material to prevent sintering or hanging of furnace charge. During the smelting process, high temperatures are also required for smooth tapping conditions. Pre-conditioned materials are easier to manage, and ZIMASCO is considering pelletising and sintering technologies in production expansion plans in order to allow safe and economic consumption of the more friable chromite ores. During the sintering process, chromite pellets are heated to a temperature where silicates fuse, binding the chromite grains. The reactions take place in an oxidizing environment, and the iron in chromite oxidises in significant amounts from Fe^{2+} to Fe^{3+}, releasing energy. The transformed grain structure facilitates the reduction phase during the arc furnace smelting stage[4]. Typical electrical energy consumption efficiencies for such processes varies between 2.0 and 2.5 MWh/MT alloy[5].

[3] The transformation of Ferrochromium smelting technologies during the last decade; J. Daavittila et al, 2004
[4] Ferroalloy Technologies, Outokumpu Steel Belt sintering technology
[5] Analysis of transport phenomena in SAF for ferrochromium production, Y. Yang *et al,*2004

One major limiting factor in the growth of the ferrochrome industry in Zimbabwe is inadequate power supply. The power generation capacity of the country has significantly deteriorated over the years and considerable investment into the power sector is urgently required. There is a need for a comprehensive policy covering energy generation, supply and management that can attract investment in the power generation sector in order to facilitate the anticipated increase in the smelting capacity.

Relative to other major ferrochrome producing countries such as South Africa and Kazakhstan, Zimbabwe is both landlocked and far from the major markets. This adds a huge distribution cost component on the product rendering the delivered much higher than its competitors. Zimbabwean producers, therefore, have to reduce the ex-works cost of production in order to compete with producers who are geographically closer to the markets. This can be achieved through improvement in efficiencies (power, Cr recoveries etc) through aggressive process improvement initiatives.

5. Ferrochrome Market Analysis

While the demand for chromium alloys has been expanding by some 5% annually over the past decade, the output of chromite ore followed closely with an average growth rate of 4.6% per annum. However, the market performance has showed an unusual pattern: Between 1994 and 1999, chrome ore production stagnated while from the year 2000 onwards, market volumes increased from about 15 million tonnes to 24 million tonnes in 2008. This substantial increase can be primarily linked to the-then rapidly rising global stainless steel demand and production in China and India. However, the onset of the economic downturn from mid-2008 saw demand for chromium plummet, with prices following a similar path. Ferrochrome consumption fell by 3.5% in 2008, in year-on-year terms, as major Asian and European consumers reduced orders to a minimum in an attempt to run down inventories, as demand from end-users declined sharply, see figure 2 above. Export prices for ferrochrome fell by 68% for the ten months to May 2009, as demand for ferrochrome from stainless steel mills collapsed. In response to weakening demand and falling prices, major producers of ferrochrome, Zimbabwe's producers included, cut production, in some cases ceasing operations all together. Around 70% of world ferrochrome production capacity was suspended in the first quarter of 2009. However, with declining inventories of ferrochrome in stainless steel mills, staggered returns to full production were initiated by producers.

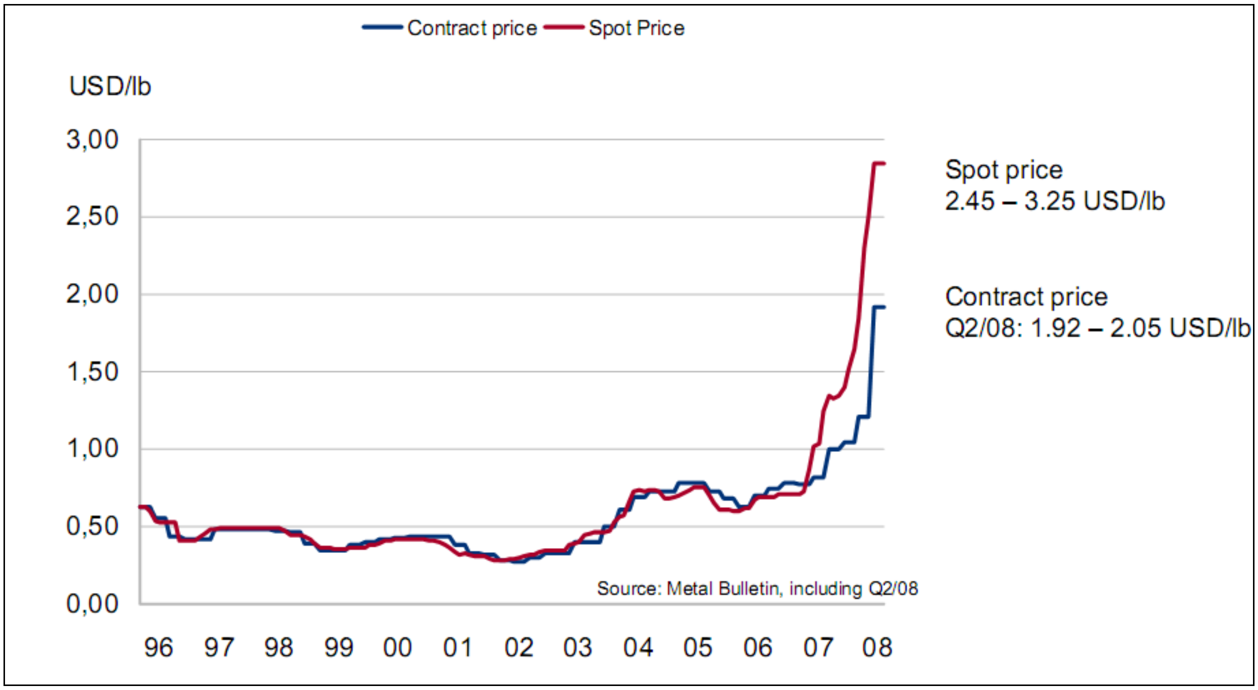


Figure 2. Ferrochrome price trend up to mid-2008[6]

6. Current and Future capacity of Chrome industry in Zimbabwe

Ferrochrome smelting technology investment in Zimbabwe has not been significant in recent years. Any investments to increase smelting capacities have to consider the pre-treatment processes of the vast stocks of chromite ore fines generated over the years from ore screening and that which is arising from the friable nature of the ore.

The production of High Carbon Ferro Chrome in submerged arc furnaces using sintered pellets in place of briquettes is comparatively better in all respects with respect to power consumption efficiencies, smoother operation of the furnace and thus increased operational efficiency, with increased "utility quotient" of equipment, leading to higher production.

The submerged-arc furnace is still the dominant technology for FeCr and FeSiCr production; however the trend elsewhere is to move to larger, closed or semi-closed furnaces, for better efficiencies in production.

The primary influences on the growth of the local ferrochrome industry include the following:

- A large portion of the chromite currently being mined requires agglomeration to achieve viable smelting efficiencies,

[6] www.outokumpu.com

- The growth in the base metals and steel industry has precipitated worldwide volatility in the price of metallurgical reductants; therefore the production capacity of the local metallurgical reductant industry has to be developed in order to cope with this demand,
- Logistical infrastructure (road/rail) is increasingly being strained by stronger global commodities demand.

Going forward, there is scope to go further in value addition by targeting stainless steel production as all the inputs e.g. scrap steel and nickel, are available locally.

7. Conclusion

Zimbabwe's chrome industry has a lot of potential as its large chromite reserves are forecast to play a significant role on the world ferrochromium supply market. This can only be achieved with more investment into the sector, which has lagged behind other minerals such as Platinum and Gold in recent years. If major projects within the sector such as pelletising and sintering plants to enable processing of fines and concentrates, Zimbawe is projected to supply between 10% and 20% of global ferrochromium demand.