RESEARCH & DEVELOPMENT INITIATIVES ON THE BRIQUETTING TECHNOLOGY AND ITS COMMERCIALISATION FOR RICHARDS BAY PLANT

R. Sen[1], D. Mukherjee[1], J. Jansen Van Vuuren[1], W. DeVilliers[1] and S. Banerjee[1]

[1] Tata Steel (Kzn) (Pty) Limited, South Africa,
senranjan102@gmail.com
mukherjee.debraj@gmail.com
jan.jansenvanvuuren@tskzn.co.za
willem.devilliers@tskzn.co.za
somdeb61@gmail.com

ABSTRACT

Tata Steel (KZN) (Pty) Ltd. (TSKZN) conducted extensive investigations on briquetting of Indian and South African Chromite Ore and Concentrate, as part of the endeavor to finalise the process technology for the Ferro Chrome Project at Richards Bay in South Africa. In production of ferro-chrome, Ore is received from the mines in the form of lumps or fines. Lumps can be fed directly to Submerged Arc Furnace but fines need to be agglomerated before charging into the furnace. As the availability of Lumpy Cr-ore is decreasing day by day, the need for agglomeration has become important. There are a few ways to convert the fines into agglomerate, which is , Sintering, Pelletisation and sintering or Briquetting. All the South African Ferrochrome producers follow the pelletisation and sintering route because South African Cr-ore is more suitable for pelletisation and sintering. TSKZN is the first plant, not only in South Africa but also globally to produce briquettes from South African Cr-ore in commercial scale, and smelt that in Closed Top Submerged Arc Furnaces. The motivations for selecting the briquetting route are low capital cost, environmentally friendly technology, simplicity of operation etc. To evaluate the possibility of briquetting South African ore, TSKZN have done a significant number of trials in pilot scale successfully. After that the commercial scale plant design, then construction started to prove the efficiency of this process in commercial scale. The plant has started briquette production from October 2008 on commercial scale and is the first briquetting plant in South Africa. Smelting of briquettes in Closed Top Submerged Arc furnace has also been started and successful up to 40% of the Ore feed to furnace

1 INTRODUCTION

Chromite ore fines and concentrates cannot be charged directly into the smelting furnaces, especially the closed top submerged arc furnaces, for reasons of safety and bad performances[1]. The fines are, therefore, agglomerated for improving the smelting conditions[2]. Various processes are available for agglomeration, e.g., sintered pellets, briquettes and chrome ore sinters[3], the first two processes being most widely used options. Although briquettes have been made extensively with chromites from India, Zimbabwe and Turkey, chromites from South Africa have never been briquetted for commercial application on continuous basis. Chrome ore briquettes have also never been used extensively in closed submerged arc furnaces. TSKZN attempted to work in these two new fronts for the first time in world, and met with reasonably satisfactory level of success with clear indications for further improvements.

2 DIFFERENT PROCESSES OF AGGLOMERATION

As already mentioned, the two major types of agglomeration processes are (i) Making Sintered Pellet, and (ii) Briquetting. Different processes of briquetting are also available as characterized by the type of binders, namely molasses, cement, dextrin, starch, sodium silicate, hydrated lime etc. In the current paper only molasses-hydrated lime-bentonite based briquetting as adopted by TSKZN, has been discussed.

2.1 Process of Making Sintered Pellets

As explained in Figure 1 below, the chrome ores received from the mines are wet ground in grinding mills, with addition of little coke fines. Then the slurry is sent to the filtering unit for dewatering and the filter cake is sent to pelletiser unit after mixing required quantity of bentonite. The green pellets from the pelletiser are then fired in belt sintering machine for sintering at 1300-1400^{o}C temperature. After sintering the green pellets get stronger and become ready for charging into submerged arc furnace as the feed[4].

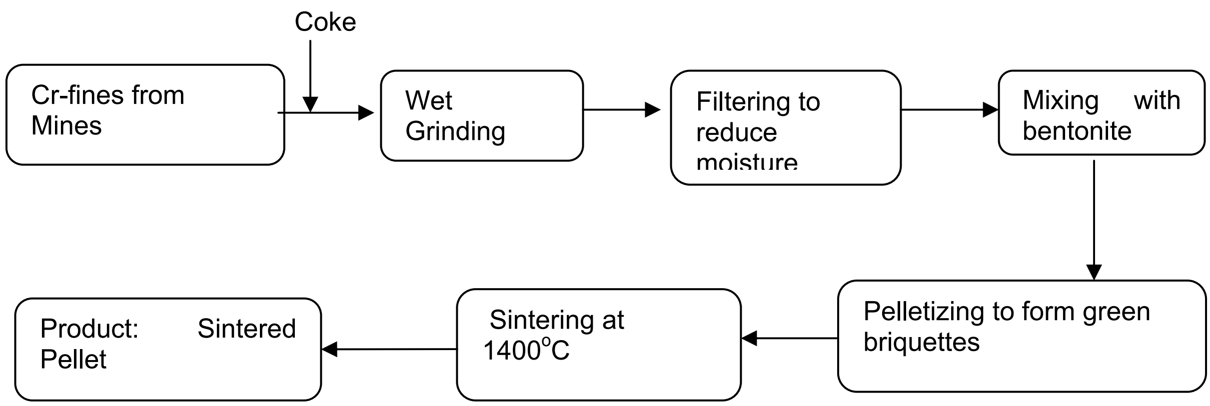

Figure 1: Flow chart for making sintered pellet

2.2 Process of Briquetting

As explained in Figure 2 below, the chrome ore fines received from mines are first dried in dryer. The dry ore is mixed with bentonite, hydrated lime and molasses, and the green mix is then fed to the briquetting presses. The presses compact the mixture at high pressure to form green briquettes. The green briquettes are stored in the storage yard for curing. After curing at ambient temperature for 24-48 hrs, the briquettes become stronger and are fed into Submerged Arc Furnaces.

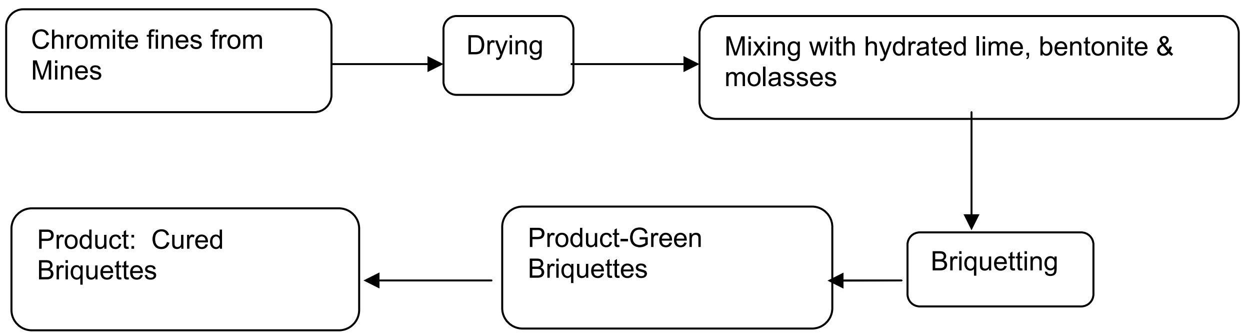

Figure 2: Flow chart for making briquettes

3 PLANT FACILITIES

The briquetting plant at Richards Bay is a completely automated plant. The major facilities of the briquetting plant are given below.

- 2 x 33 t/h Briquetting Presses
- 2 x 30 t/h Rotary Dryer
- 2 Nos. High Energy Intensive Mixers
- 1 x 3000 cu.m Molasses Storage Tank
- Molasses preparation and dosing system
- Conveyors, bucket elevators, loss-in-weigh feeders
- 120 t/h capacity Stacker

Two Submerged Arc Furnaces of 38 MVA capacity each are used for smelting.

3.1 Details of the Briquetting Presses

1.1.3 Technical data

Roller diameter (nominal diameter)	750 mm
Working width of pressing tool	310 mm
Type of pressing tool	Strip segments
Total weight of machine	19300 kg

3.1.2 Operating data

Product capacity	nominal	31.5 t/h
Speed	nominal	16 rpm
	Min., variable	10 rpm
	Max.	20 rpm
Drive rating	nominal	150 kW
	At n=max	182 kW
Specific pressing force	nominal	40 kN/cm
	Max	52 kN/cm
Total pressing force	nominal	1240 kN
	Max.	1508 kN

4 RECIPE FOR BRIQUETTES

Briquettes need to have high hot strength to combat disintegration under load and high temperature conditions prevailing inside the furnace. Besides hydrated lime and molasses conventionally used for chrome ore briquettes, TSKZN used bentonite as the additional binder to promote hot strength as required for closed SAFs. All the binders, namely, molasses, hydrated lime and bentonite are sourced from local South African suppliers

5 SIZE OF THE BRIQUETTES

Briquette volume (nominal volume)	27cm^3
Briquette size	46.7 mm x 33.5 mm x 27.0 mm
Specific weight of briquettes	3.2 gm/cm^3 (approx)

6 COMPARATIVE FEATURES OF BRIQUETTING AND SINTERING

Features of the processes of briquetting and sintering are presented in Table 1 below.

Table 1: Comparison of various features of briquetting and sintering processes

Sl. No.	Parameters	Sintering (Outokumpu Process, Finland)	Briquetting (with Binders tried by TSKZN)
1.	Capital Cost	Very high	Low
2.	Design and Engineering	Fairly complicated	Very simple, involves normal material handling modes
3.	Intellectual Property Rights (IPR)	Applicable in favour of Outokumpu	Covered by IPR by Tata Steel
4.	Royalty Fees	Applicable	Applicable in favour of Tata Steel
5.	Supervision cost during erection	High	Moderate
6.	Ramp-up period	75% in 6 months, 90% in 12 months	50% in 1st month, 75% in 3 months, 90% in 12 months.
7.	Use of CO rich Furnace off-gas for process	About 40% of the export gas needs to be used for sintering of the green pellets	Briquetting being a room temperature process, does not need to use the CO rich furnace off-gas for any process needs. However, heat-hardening remains a possibility, but that being a lower temperature process, will consume lower amount of gas
8.	Issue of generation of suspected Carcinogenic Cr^{+6}	Sintering takes place at a temperature as high as 1400°C, leading to generation of suspected Carcinogenic Cr^{+6} through oxidation	Briquetting being a room temperature process, there is absolutely no question of generation of Carcinogenic Cr^{+6} through oxidation. This process, therefore, is much more friendly to the environment.
9.	Potential of Co-generation of Power	As a substantial portion of CO rich furnace gas is to be used for sintering of pellets, the quantum of surplus gas is normally not adequate to justify a captive power plant economically.	Availability of significantly high quantity of surplus CO rich furnace gas ensures co-generation of electrical power very efficiently through the use of modern power plant equipment. This also attracts Carbon Credit additionally, which is commercially attractive and satisfies the Corporate commitment to a cleaner environment.
10.	Plant availability	98%	97%
11.	Specific power consumption	low	marginally higher
12.	Cost of production	High	Low

7 STEPS TAKEN ON PROCESS DEVELOPMENT AND ENGINEERING

The following steps were taken by TSKZN for development of the briquetting process and design, engineering, erection and commissioning of the briquetting plant. The activities are listed in chronological order.

- 1st briquetting test work was conducted in the pilot plant in Germany with Indian Ore in April 2004.
- The briquettes made from Indian ore, were charged into the 30 MVA Submerged Arc Furnace of Tata Steel's own Ferro-Chrome Plant in Bamnipal to the extent of 70% of the furnace feed and the trial continued for 17 days. Among the different types of Submerged Arc Furnaces, Closed Top Submerged Arc Furnace is the most environmentally friendly and was the selection of TSKZN for Richards Bay plant. But briquettes in high proportion were never tried in Closed Top Submerged Arc Furnace earlier. The success of Bamnipal trial paved the way for TSKZN to finalize the selection of briquetting in Closed Top Submerged Arc Furnace.

- Based on the above two trial data available, basic engineering, designing of the briquette plant started from end of 2006.
- 2nd briquetting test work was conducted in the same pilot plant in May 2007 to test the suitability of South African ore for briquetting.
- Based on the trial results certain modifications are done in the plant design that had already started.
- Construction of the briquetting plant started from the month of April 2007 and completed by end September 2008.
- South African operators were trained in briquette plant operation because briquetting was an unknown technology in South Africa.
- The commissioning activities of the plant with South African ore started from the month of October 2008 and continued for one month. By the end of the month the first batch of briquettes were made from South African chrome ore concentrate. The quality of the briquettes was even better than the trial results.
- After that, the challenge was to increase the production and reach up to the rated capacity and subsequently feed the briquettes to the Submerged Arc Furnaces. The production and availability of briquetting plant improved over the months November 2008 to March 2009.
- Subsequently feeding of briquettes into the furnaces started from the month of November 2008, with an effort to increase it as much as possible, keeping the other parameters undisturbed. Proportion of briquettes in the furnace charge has been reached up to 40% of total chromite feed.

8 IMPORTANT MILESTONES

- First briquette production with molasses and hydrated lime: 26th October 2008
- Declared Commissioning of Briquetting Plant: 27th October 2008
- First briquette charged into smelting furnace: 21st November 2008
- First briquette production with bentonite as the additional binder: 3rd December 2008
- First Despatch of product Charge Chrome using Briquettes: Huangpu Port, China for Lianzhong Stainless Steel Corporation

All the above developments related with briquetting have taken place for the first time in the world.

9 CHALLENGES AHEAD

Since briquetting technology was adopted by TSKZN for the first time for (i) South African chromites and (ii) closed submerged arc furnaces, the route for implementation of the technology was not very smooth. Many unforeseen problems came up. While some of them have been already addressed successfully, some problems still remain to be solved. These are the challenges before TSKZN. These challenge areas have been identified and TSKZN is confident to overcome them. The issues to be addressed are given below.

9.1 Production Capacity

Upto 80% of the rated production of the Briquetting Plant has been achieved. It is required to reach 100% level. The planning has already been done and a list of modifications required to achieve has been prepared. The modifications are under implementation.

9.2 High Cost Due to Wear of Segments

Presently the cost of production is slightly on the higher side against internal targets set. One of the reasons of that is South African chromite ore is highly abrasive, resulting in rapid wear of costly press segments, compared to Indian ore. TSKZN is looking at development of different type segments, which will bring down the cost per ton of production.

9.3 Generation of Fines

Generation of fines upto 20% (maximum) is experienced currently at the stage of screening of briquettes before feeding into the furnaces. Process modifications are underway. The target is to reduce fines to less than 10%. On the other hand, usage of recycled fines in making briquettes gives it higher strength – and hence it would be necessary to strike a judicious balance.

9.4 Problem in Thickener

Up till now it has been possible to charge briquettes in the furnaces upto 40% of ore feed, though it was planned to charge upto 75% into the furnaces. The reason is explained as follows. Molasses based briquettes have been used for the first time in closed furnaces. The gas cleaning plant of a closed furnace is equipped with wet scrubbers as against dry gas cleaning plant for a semi-closed furnace. Molasses of the briquettes gets evaporated and comes out with the furnace gas. When the furnace gas is scrubbed, the molasses gets dissolved in the water and goes to thickener. In the thickener solids are separated from liquid by gravimetric separation. But molasses dissolved in water of the thickener makes a kind of froth with the fine solid particles and this froth does not allow the solid dusts to settle down efficiently. This leads to frequent thickener jamming and is undesirable for smooth furnace operation.

10 ACTION PLANS TO MEET CHALLENGES

10.1 Plant Modifications to Increase Production

After the ongoing design modifications are over, the plant can work at the rated capacity.

10.2 Reduced Wear of Segments

10.2.1 Change of segment dimensions

TSKZN has planned to increase the size of the briquettes keeping the shape unchanged. Accordingly segments with bigger pocket size have been ordered. In this way it will be possible to increase the tonnage of product per revolution of the press. This will result in reduction of the amount of wear of segments per ton of briquettes. The dimensions of the bigger size briquettes are given below.

Briquette volume (nominal volume)	60 cm^3
Briquette size	62 mm x 53 mm x 36 mm
Specific weight of briquettes	3.2 gm/cm^3 (approx)

Once the trial with bigger size segments is done, the compressive strength and shatter strength of the bigger briquettes will be checked, and these larger briquettes will be charged into the furnaces to see the suitability of such briquettes with regard to the operation of closed submerged arc furnaces. Typically, it should give better results.

10.2.2 Segments of lower cost

Development of vendors for cheaper press segments is in progress to reduce the cost of production of briquettes.

10.3 Heat Hardening of Briquettes

So far briquettes have been heated at around 1000^{o}C in pilot scale in muffle furnaces. Many improvements as listed below have been observed.

- Improvement in surface hardness of briquettes
- Increase in hot strengths
- Increase in porosity
- Molasses was evaporated. This can give benefits in operation like reduction in specific power consumption, and elimination of thickener problem.

However, it should be noted that even heating to 600^{o}C is adequate, as at that temperature the characteristics are almost similar to that at 1000^{o}C. Hence heating to a higher temperature may not be necessary.

10.4 Alternative binder

TSKZN is currently busy in identifying the possibility of using binders other than molasses to sort out the problem of choking of thickener. In this regard a short trial with Sodium Silicate has been done as an alternative binder for briquetting. The results are quite encouraging. The strength of the briquettes, with Sodium Silicate as a binder, is at par or higher than that with conventional molasses briquettes. Effect of heating of the briquettes made with sodium silicate, have also been studied. Compared to molasses based briquettes, same degree of improvements in strengths, have been attained at lower temperatures of heating. An industrial scale trial has been planned in the coming months with Sodium Silicate as a replacement binder of molasses.

11 OPERATING RESULTS

11.2 Average Composition of Feed Ores and Briquettes

Lumpy ore and briquettes have been used as the feed chromite to the furnaces. Average compositions of lumpy ores, concentrates and the briquettes produced are given in Table 2.

Table 2: Average composition of feed

Material	Cr_2O_3%	SiO_2%	Fe(tot)%	Al_2O_3%	MgO%	P%	S%	Cr/Fe
Lumpy	35.64	14.50	16.15	12.69	11.71	0.005	0.006	1.57
Concentrate	41.21	4.41	20.53	13.80	11.40	0.003	0.004	1.37
Briquette	38.34	3.77	19.06	15.97	9.89	NA	0.035	1.38

11.3 Average Composition of Product

Average composition of product ferrochrome is presented in Table 3.

Table 3: Average composition of product ferrochrome

Cr%	Si%	Fe%	C%	S%	P%
50.27	4.58	36.73	6.79	0.046	0.022

11.4 Strength of Briquettes

Shatter strength, cold compressive strength and compressive strength under hot conditions at 1000°C are given in Table 4 below for briquettes made from Indian concentrates as well as South African concentrates. Results are comparable, and the hot compressive strengths for the briquettes made from SA concentrates are better than Indian case.

Table 4: Strength of briquettes achieved by TSKZN

Parameters	Briquettes from Indian Concentrates	Briquettes from SA Concentrates
Shatter Strength %>20 mm	86 - 93	85 - 99
Cold Compressive Strength, Newton	380 - 930	340 - 1300
Hot Compressive Strength at 1000°C, Newton	600 - 1200	700 - 2790

12 COMPARISON OF PERFORMANCES

Various furnace operating performances for operation with lumpy ore, briquettes and sintered pellets have been compared and the comparative figures are presented in Table 5 below. It is to be noted that the figures for operations with briquettes are based on 40% briquette usage. The indices are expected to be better once 75% briquette is charged into the furnaces.

Table 5: Comparison of operating performances with briquettes and sintered pellets

	Feed to Furnace	Specific Energy Consumption, MWH/T FeCr	Slag/Metal Ratio	%Cr2O3 in Slag	Cr Recovery, % (Liquid Metal Basis)
TSKZN Experience	100% Lumpy	3.722	1.18	~11.5	85.02
	60% lumpy+40% briquette	3.380	1.20 – 1.22	9.0 – 9.5	90.76
Sintered Pellets	70-80%pellets+ lumpy ore	3.300	1.2 – 1.3	10 - 14	82 - 89

13 PATENT ISSUES

After the success attained in establishing the briquetting technology on a commercial scale, TSKZN has acquired the Intellectual Property Right (IPR) for the new and novel process. The IPR is applicable on global basis. TSKZN will soon be ready to transfer the technology to users interested to set up such plants.

14 CONCLUSIONS

1. TSKZN is the first to adopt briquetting as the commercial process for agglomeration of chrome ore fines/concentrates from South Africa.
2. TSKZN is also the first producer of ferrochrome globally to charge briquettes in closed submerged arc furnaces for producing ferrochrome successfully.
3. Bentonite has been used as a binder over and above molasses and hydrated lime, conventionally used binders for briquetting, and significant improvements in hot strengths have been obtained.
4. As expected for any new technology, many new challenges have been faced during commercialisation of briquetting process. Many of these shortcomings have been eliminated through modifications in design, engineering and process. The plan for overcoming the gaps still remaining have been done, and modifications are in progress.
5. Operating results with usage of briquettes are comparable with, and in some cases better than those with operation with sintered pellets
6. Heat hardening of briquettes at moderately high temperatures can improve the quality of the briquettes and the operating performances.
7. Investigations with sodium silicate as alternative binder are in progress. After laboratory scale tests, industrial trials are lined up in December 2009.

15 REFERENCES

[1] Ray, C.R., Sahoo, P.K., Rao, S.S., Strength of chromite briquette and its effect on smelting of charge chrome / ferrochrome, INFACON XI, Proceedings of the 11th International Ferroalloys Congress, New Delhi, 2007.
[2] Rath, G., Rottmann. P., Use of briquetted feed for the production of ferro chrome, Proceedings of the 38th Electric Furnace Conference, Pittsburg, 1980, pp.128-132.
[3] Shoko, N.R., Malila, N.N., Briquetted chrome ore fines utilization in ferrochrome production at Zimbabwe alloys, INFACON X, Proceedings of the 10th International Ferroalloys Congress, Cape Town. 2004, pp.291-299.
[4] "Turning pellets into profits", website of Outotec, Finland available at http://www.outotec.com/37991.epibrw