NEW PROCESS FOR SINTERING CHROMITE CONCENTRATE WITH CONTINUOUS-STRAND SINTER MACHINE

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ABSTRACT

The present authors wish to find out the Chinese way to sinter the chromite fines with the aim to reduce the cost, at the same time, obtain high quality sinter. The possibility to use continuousstrand sinter machine for sintering chromite concentrate was studied in the present paper. The effects of proportioning, temperatures and sintering duration time on sinter's properties were investigated and the relative optimized sinter parameters were obtained by experiments in laboratory. The results indicated that the products obtained from sintering pot could meet the requirements of materials for big furnace production. And with the new process, the sintering efficiency has been improved a lot compared with the normal sintering process currently used in China.

KEYWORDS: *Chromite concentrate, pelletizing, sintering, properties, contious-stand sinter machine.*

1. INTRODUCTION

Nowadays, the major materials for Ferrochrome (FeCr) refining are lumpy ores and fine ores. In order to meet the requirements of permeability during production, lumpy ores are more proper to be used directly [1] for smelting in Submerged Arc Furnace (SAF) rather than fine ores. However, fine ores (less than 8mm) takes place 80% the production of ferrochrome ores every year in the word [2, 3]. At the same time, fines have higher grade and lower price compared with lumpy ores. Hence it is economical efficient to use fines properly. It is reported that cold agglomeration for ferrochrome fines is one of effective ways to use the fines [1, 4]. Currently, Outotec technology of sintering and pre-reduction technology in kiln from Japan are normally used for ferrochrome concentrate (FeCr) sintering process in South Africa (SA). In Outotec process, concentrate and additives are pelletized with a cylinderical pelletizer and then sintered on a steel belt. The capital costs for these two processes are both very high. Besides, during pre-reduction process, the materials are easy to attach on the kiln's wall, which needs periodic cleaning, and further affect the continuous production. Hence these two ways have not been used in production in China till now.

Recently, more and more FeCr producers in China are focusing on the sintering of chrome fines to run the big furnace. Because sintering process is essential for ensuring the properties of materials charged into the furnace, ultimately guarantee FeCr production, especially for bigger furnaces. Some of the FeCr producers intend to use the iron ore sintering process (Continuous-strand Sinter machine) which is mature in China. In this way, chromite concentrate is directly put in the pot after proportioning and sintered by burning carbon and exhausting the air (This method is called old process hereafter). However, there are two drawbacks of current sintering method concluded from the experience of several plants which are using it. First is that the efficiency of sintering and sintering speed are both relative lower, while, the second is that the quality of the sinter is not ideal for a big furnace. Present authors have done some test on the sinter, the high temperature properties of the sinter is good, listed as following:

1) Reduction degradation index under 500℃, $RDI_{+3.5}$=94.1%;
2) The softening point under load : T_{BS} =1186℃, ΔT_B=212℃;
3) The reducibility RI=28.6%.

However, the drum index of the sinter is very low (42%). The drum index indicates the mechanical strength of the sinter. Small drum index means that the sinter will be broken down into fines during handling, transport, stocking, charging and the following down within the furnace, which will cause the problem for smelting process, especially for a big furnace.

Some researchers were trying to find out the Chinese way to sinter the ferrochrome fines in order to solve the problems stated above, viz. pelletizing and sintering afterwards with continuous-strand sinter machine. For example, Zhu Deqing et al [3, 5] have developed a pelletizing and sintering way to make ferrochrome pellets, and they got good results in the big size experiment with sintering pot in lab. However, the effects of sintering time and temperatures to properties of sinter have not been systematically studied. It is known that chromite fines has bad pelletizing properties and bad permeability of the materials during sintering process, hence it is important to develop a proper process to sinter the fines by continuous-strand sinter machine and find out the basic technical parameters for this process, which will be studied by present authors and discussed partly in this paper.

2. EXPERIMENT

2.1 Materials

The materials for present experiments are: one type of SA chromite concentrate, binder, coke et al.. The compositions of chromite concentrate are listed in table 1. It is seen in table 1 that Cr_2O_3 content of this ore is 42%, meanwhile the harmful elements like S, P et al. are not high, which will meet the requirements for materials used in practical production.

It has been proved by practice that the pelletizing properties of ferrochrome fines are not good, and the specific surface area needs to be more than 1700 cm^2 /g to ensure that it could be pelletized [6]. Refer to literatures [3, 5, 6], chromite concentrate were milled into fines before doing proportioning, in which, the ratio of materials with size less than 0.074 mm (200 mesh) will be more than 80%.

Table 1: Chemical analysis of chrome fines

Components	**Iron oxide**	**Cr_2O_3**	**SiO_2**	**Al_2O_3**	**CaO**
Content(mass%)	28.2	42.0	3.0	15.6	0.44
Components	**MgO**	**TiO_2**	**MnO**	**P**	**S**
Content(mass%)	9.02	0.83	0.23	0.007	0.008

2.2 Experimental procedures

Chromite concentrate were milled first into fines less than 200mesh and then pelletizing experiments will be carried out before running sintering experiment. The experimental procedure is shown in figure 1.

The experiments were carried out step by step, means the experimental scale will be enlarged gradually. Pelletizing experiments will be carried out firstly with the aim to optimize the parameters to make the pellets. Proper pellets were selected for sintering experiments. The small amount materials (500 g) will be sintered in a high temperature resistance furnace (HTRF). At this stage, the impact of carbon content, sintering temperature and sintering time on sinter's properties will be investigated. The result will be analyzed and proper conditions will be repeated in pilot experiments of 40 kg pellets by a sintering pot.

Figure 1: The experimental flowchart

Pelletizing experiments were carried out by a disc pelletizer with 8 kg materials each time. However, the result for pelletizing experiments will not be discussed here. Only sintering experiments will be discussed in this paper

2.3 Pilot experiments by sintering pot

Pilot experiments will be carried out in a batch sintering pot, which is separate part of continuous-strand sintering machine. The materials are 30-40 kg while the height of materials is 500-700 mm. The temperature will be monitored by thermocouples during experiment at different positions of the pot, which are 150 mm and 250 mm high from bottom respectively, as shown in figure 2.

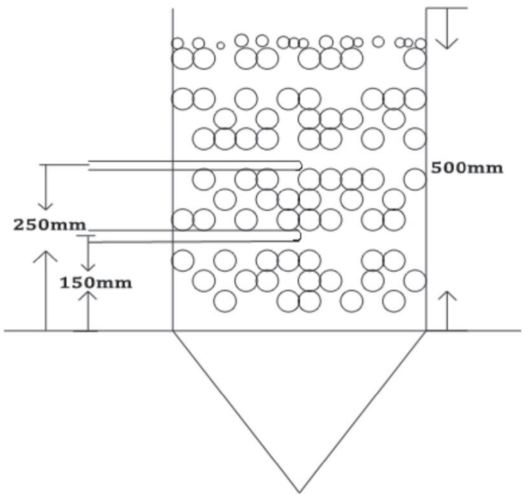


Figure 2: Sketch of sintering pot

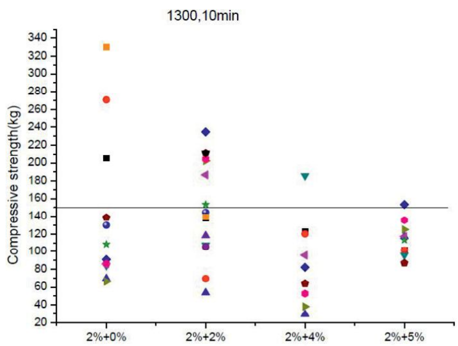
The properties of sinter obtained from pilot experiments were tested, like compressive strength of the pellets, reduction degradation index, softening point under load et al.

3. RESULT AND DISCUSSIONS

The sintering experiments were carried in a muffle furnace with the sintering temperature at 1300°C, 1325°C and 1350°C, meanwhile, the sintering duration time is 10 min and 15 min. Compressive strength of pellets have been measured afterwards.

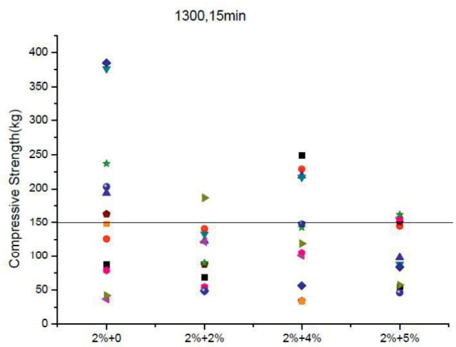
3.1 The effect of carbon and sintering duration time on compressive strength of sintered pellets

The way for carbon proportioning is inner adding combined with outer adding. The amount of carbon added is varying from 2% inner carbon+0% outer carbon, 2% inner carbon +2% inner carbon, 2% inner carbon +4% inner carbon, 2% inner carbon +5% inner carbon. Sintering duration time is 10 min and 15 min respectively. The results are shown in figure 3.



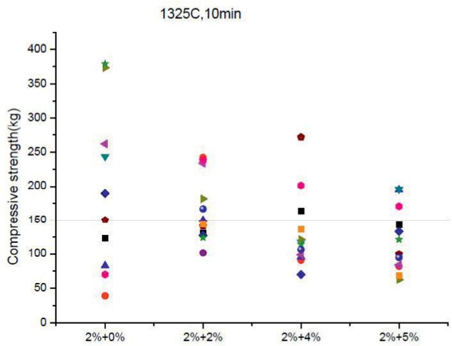
Carbon (mass%)

a) 1300℃, sintering for 10 min



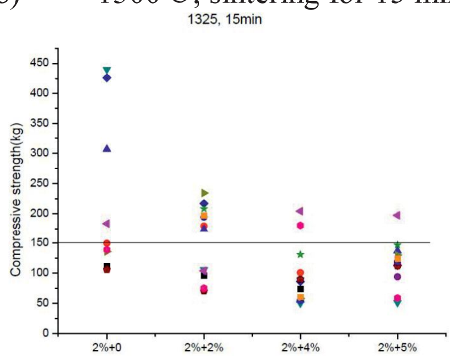
Carbon (mass%)

b) 1300℃, sintering for 15 min



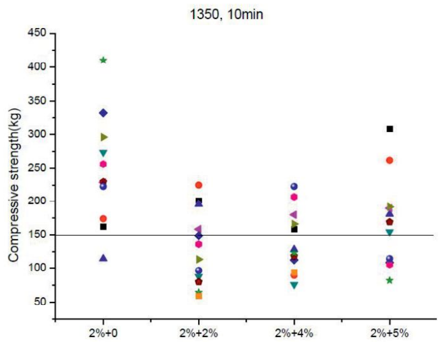
Carbon (mass%)

c) 1325°C, sintering for 10 min



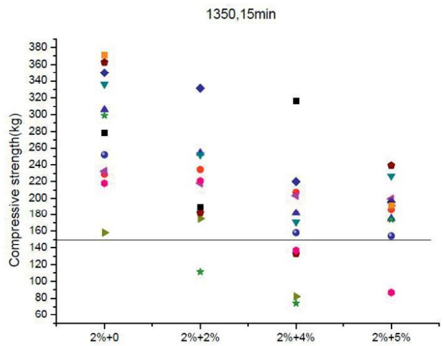
Carbon (mass%)

d) 1325℃, sintering for 15 min



Carbon (mass%)

e) 1350°C, sintering for 10 min



Carbon (mass%)

f) 1350°C, sintering for 15 min

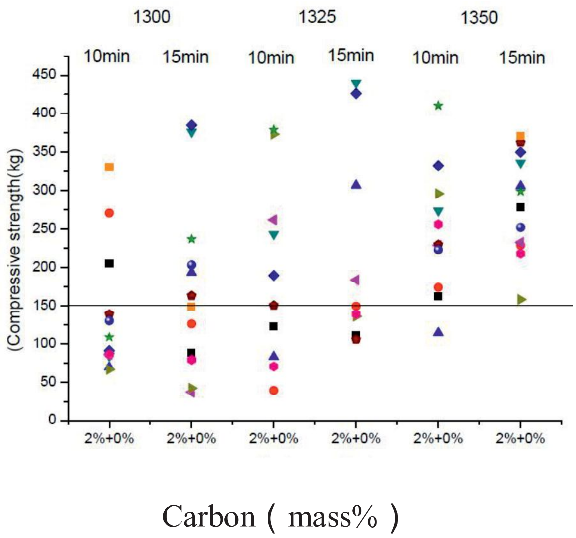
Figure 3: The effects of carbon content and sintering time to compressive strength of sintered pellets

It is seen from figure 3 that, with increasing of carbon content, the compressive strength of sintered pellets decreased, and this trend is more obvious at 1300℃ and 1325℃, while not notable at 1350℃.

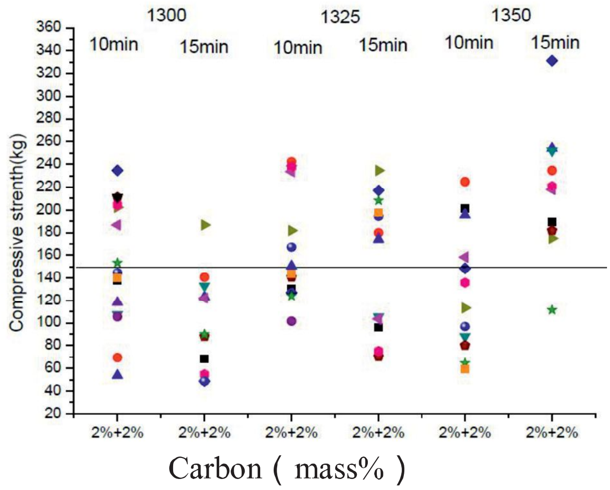
At the same sintering temperature, as shown in figure 3 (a) with (b), (c) with (d), (e) with (f), as long as the sintering duration time reach 10 min, there is no big influence of sintering time to compressive strength of sintered pellets.

3.2 The effect of temperature on compressive strength of sintered pellets

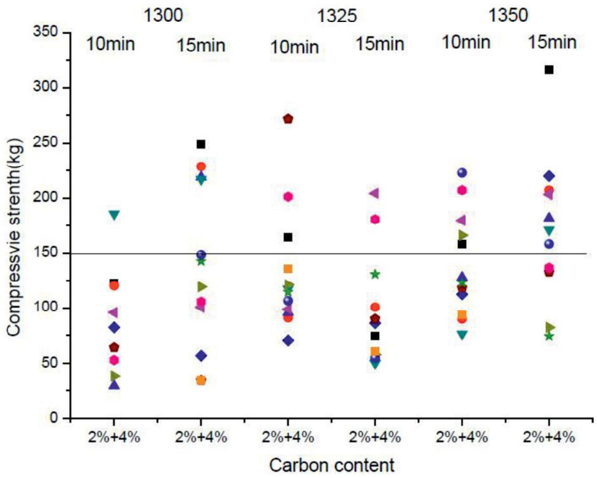
Green pellets with different proportioning will be sintered for 10 min and 15 min at 1300℃, 1325℃ and 1350℃ respectively, and then measured compressive strength. The results are shown in figure 4.



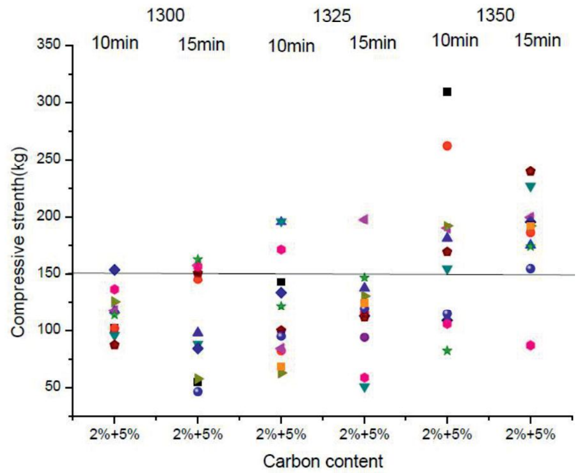
a) Inner carbon of 2%,outer carbon of 0%



b) Inner carbon of 2%, outer carbon of 2%



c) Inner carbon of 2 %, outer carbon of 4%



d) Inner carbon of 2 %, outer carbon of 5%

Figure 4: The effect of temperature on compressive strength of sintered pellets

It can be seen from figure 4 that, it has big effect of temperature on compressive strength of sintered pellets. At same carbon content and the same other conditions, higher compressive strength was obtained at higher temperature. It needs to be pointed out that, with outer heat resource, sintering duration time has not big effect on strength of sintered pellets.

Combined figure 3 and figure 4, at inner carbon 2%+ outer carbon 2% and temperature of 1300℃, after 10min sintering, around 86% pellets are with compressive strength of higher than 100 kg, while sintering for 15 mins,45% pellets with the strength over 100 kg. At 1325℃, 74% pellets could reach 100 kg compressive strength after 10 min sintering while sintering for 15 min, 100% pellets could reach 100 kg strength. However, at temperature of 1350℃, after sintering for 10 min, around 58% pellets are over 100 kg strength while with 15 min sintering, all of pellets could reach 100kg strength, moreover, the pellets with strength over 150 kg is more than 90%. That indicated ideal sintered pellets could be obtained when temperature reaches 1350℃ and sintering time of 10 mins with carbon content of 4%.

3.3 The results of experiments with sintering pot

On the basis of small scale experiments in muffle furnace, pilot experiments were carried out in a sintering pot with amount of 30-40 kg. Pellets for sintering are in two sizes of 10-12 mm and 5-8 mm. The samples were picked randomly from different layers in the pot after sintering to do relative tests. The properties of sintered pellets were measured and compressive strength of the pellets is shown in figure 5.

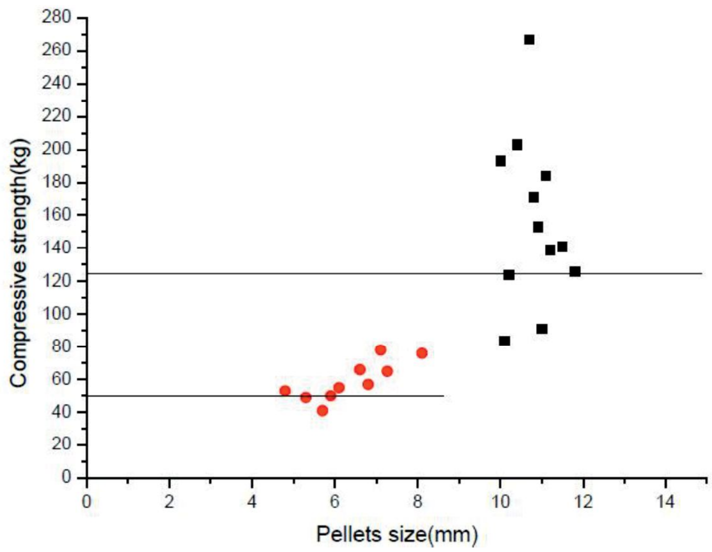


Figure 5: Compressive strength of sintered pellets obtained from sintering pot

It is seen from figure 5 that, compressive strength of bigger pellets are higher than that with smaller size. All of big pellets (10-12 mm) could reach 80 kg strength and almost 80% pellets have strength of more than125 kg, maximum 270 kg. For small pellets, their compressive strength is in the range of 50 kg ~ 80 kg and the strength distribution for pellets is uniform.

The sintering pot experiment is finished around 40mins with the time counted from ignition, and the maximum temperature of 1440℃ was obtain at the bottom of the pot. At the position of 25 cm high from bottom, the duration for temperature higher than 1300℃ is 3min and 30 sec. The products obtained from above situation has low pulverization ratio with the rate of finished products over 90%. And more than 80% pellets could reach the strength of 125 kg, maximum strength of the pellets is 270 kg. The production time with new method has been reduced a lot compared with the old process, which used to be 1.5 hours to get the sinter.

3.4 Comparison of properties for normal sinter from old process and pellets from new process

Pellets obtained from new process(Pelletizing first and then sinter by continuous-strand sinter machine) were compared with the sinter got from old process (Fines were directly put on continuous-strand sinter machine) and results are listed in table 3.

Table 3: Comparison of properties for normal sinter from old process and pellets from new process

Properties	Production time	Drum index	Reduction degradation index			Softening point under load		
			$RDI_{+6.3}$	$\mathbf{RDI_{+3.15}}$	$RDI_{-0.5}$	T_{BS}	T_{BE}	ΔT_B
Normal sinter (Old process)	90 min	42%	93.1%	**94.1%**	3.1%	1186℃	1398℃	212℃
Pellets (New process)	40 min	91%	97.7%	**97.7%**	2.3%	1146℃	1398℃	252℃

It can be seen from table 3 that the reduction degradation index $RDI_{+3.15}$ for pellets from new process is higher than the normal sinter, which indicated that the products got from new process are not easy going to pulverization hence have better permeability during reduction. That guarantees the fluent production for smelting furnace. The softening point under load for two kinds of products are similar, which indicates that these two products are both having good strength under load at high temperature, but the pellets from new process are a bit better.

It is very obvious that the production time for old process is around twice of that for new process, that is because after pelletizing homogenously, the permeability of sintering materials are much better, hence it is easy and quick to sinter. This indicates that with new process, it is not only could get better products with good properties, meanwhile the sintering efficiency has been enhance largely. That brings big possibility to use continuous-strand sinter machine for sintering during production with big furnaces.

4. SUMMARY

It could be summarized briefly through the experiment that:

1) Temperature has big effect on compressive strength of sintered pellets. During 1300-1350℃, higher compressive strength was obtained at higher temperature.

2) With the sintering duration time of 10-15 min, duration has no big effect on compressive strength of sintered pellets. At present experimental conditions, higher carbon content will bring lower strength of products at 1300℃ and 1325℃. At 1350℃, carbon content has almost no effect on strength, which indicates that temperature dominates the strength of sintered products.

3) The products obtained from sintering pot could meet the requirements of materials for big furnace production. And with new process, the sintering efficiency has been improved a lot. That provided the technical possibility to use continuous-strand sinter machine big furnace production.

5. ACKNOWLEDGEMENT

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