

EVALUATION OF SELECTED TECHNOLOGICAL AND ECOLOGICAL PARAMETERS OF SINTER PRODUCTION

M. Džupková, M. Fröhlichová, J. Legemza, R. Findorák

Department of Ferrous Metallurgy and Foundry, Faculty of Metallurgy, Technical University of Košice, Slovakia

Received 14.09.2011

Accepted 16.12.2011

Corresponding author: M. Džupková, Tel: +21 55 602 3153, E-mail: martina.dzupkova@tuke.sk, Department of Ferrous Metallurgy and Foundry, Faculty of Metallurgy, Technical University of Košice, Slovakia

Abstract

Agglomeration of iron ore materials represents one of the methods of iron ore preparation. This process takes place in the gas-liquid-solid phase system, where the gaseous phase ensures the course of decisive processes (fuel burning, heat transfer, oxidation and reduction processes), while the liquid phase is generated by melting of the fine grained iron ore particles and alkali materials. The agglomeration process produces solid porous agglomerates, which represent the basic component of blast furnace charge. However, agglomeration plants are among industries that contribute significantly to environment pollution. The aim of our experiments was to analyze the effect of selected parameters of sintering on the formation of gaseous and particulate matter pollutants with regard to the agglomerate quality. On the basis of the theoretical knowledge the effect of the sucked air under-pressure and humidity of the agglomeration mixture, the regulation of which can contribute to the reduction of environmental burden of emissions, was examined under laboratory conditions. The research included seven sintering procedures, the diversity of which was ensured by the change of technological parameters of the agglomeration process. Pollutant concentrations were recorded by combustion product analyzers; the agglomerate quality was monitored by tests in accordance with STN standards.

Keywords: sintering, underpressure sucking air, humidity, particulate matter.

1 Introduction

The recent trend of using metal materials worldwide is permanently focused on the development of steel production. From this perspective the preparation of charging stock for pig iron production is very important with regard to economic and environmental aspects of this process. Global warming and climate changes are the current worldwide environmental problems. The Kyoto Protocol, which became effective on February 14, 2005, is the only initiative against climate changes. The main goal of countries which committed to adhere to the agreement of this protocol is to reduce greenhouse gas emissions by 8 % compared to level from year 1990. In accordance with new agreements, leaders of individual member states have agreed upon increasing the total share of renewable energy sources to 20 % by 2020 and simultaneously decreasing greenhouse gas emissions by 20 – 30 % during the same time period [1-2]. CO₂ emissions generated by burning fossil fuels contribute to the global warming of the Earth.

Therefore it is important to search for new technologies the use of which could result in the reduction of fossil fuels used in industries [3-5]. The agglomerate production is both power and material consuming and environmentally demanding. The gaseous phase originating in the agglomeration process contains significant amount of pollutants, which pollute the environment. In addition to carbon oxide emissions, SO₂, NO_x and particulate matter pollutants, the agglomeration process is also a source of dioxin contamination [6-7]. The reduction of the environmental burden caused by emissions can be achieved through the use of suitable, high quality charging stock as well as by means of regulation of selected sintering parameters (sintered bed thickness, quantity and speed of sucked air, quantity and type of fuel, concentrate-to-agglomeration ore ratio etc) [8-11]. The regulation of the sucked air under-pressure can influence not only the quantity of pollutants, but also the quality of produced agglomerates [12-13]. The particulate matter (PM) quantity is significantly affected by the mixture humidity and the quantity of fuel. Authors [14] have found that the increase of humidity level from 5.5 % to 9 % results in the decrease of particulate matter concentrations in combustion products, while the increase of coke from 5.5 % to 7.5 % results in its increase. The research focused on the reduction of NO_x emissions showed that nitrogen oxide concentrations can be reduced by controlling combustion in the sintering process. Nowadays, the use of high quality fuel with low nitrogen content is one of the methods that can be used in agglomeration plants [15].

2 Experimental materials and methods

The laboratory experiments included seven measurements which aimed at determining the effect of selected technological parameters (charge humidity, under-pressure) on the quantity of pollutants, with regard to the agglomerate quality. The sintering was performed in a laboratory-scale pan with the capacity of 0.121 m³; the weight of each charge was approximately 240 kg. The slight differences in weight between individual experimental mixtures were caused by the effect of various bulk densities of charge. One of the possibilities of optimizing the sintering process is the control of the charge permeability, which in case of laboratory experimental sintering was achieved through various levels of moistening of the charge. The charge permeability subsequently affects the quantity of sucked air, while the sucked air speed determines the under-pressure values. In sintering procedures No.1 to No.7, the humidity was changed within the range of 4.5 % - 8.5 % during these experiments. Sintering No.7 was simulated so that the negative impact of the low mixture permeability, low humidity and under-pressure on the sintering duration, quantity of emissions and agglomerate quality were demonstrated. As the mixture permeability value was only 0.25 m³/min and the humidity value was 4.5%, the experiment failed as expected, so the granulometric analysis, ISO testing and other quantitative parameters could not be established. In addition to the charge humidity, also the effect of under-pressure, which changed within the interval of 4.5 kPa – 7.2 kPa, was monitored during the experimental sintering procedures. The laboratory sintering parameters and the chemical composition of the sintered mixture are shown in **Table 1**.

3 Results and analysis

The chemical composition and size distribution of agglomerates produced under laboratory conditions are shown in **Table 2**. **Table 3** displays concentrations of pollutants in combustion products recorded during experimental sintering.

Table 1 The laboratory sintering parameters and the mixture chemical composition

	sintering 1	sintering 2	sintering 3	sintering 4	sintering 5	sintering 6	sintering 7
permeability [m ³ /min]	0,58	0,6	0,5	0,65	0,6	0,5	0,25
humidity [%]	7	8,5	5	7	7	7	4,5
underpressure [kPa]	7,2	6,5	6	6,2	4,5	4,5	4,5
speed of sintering [mm/min]	13,35	13,51	11,41	12,88	9,6	8,69	
chemical composition [%]							
Fe	52,28	50,82	52,39	52,39	52,39	52,39	52,39
FeO	11,5	11,06	11,06	11,06	11,06	11,06	11,06
Fe ₂ O ₃	62,01	60,41	62,66	62,66	62,66	62,66	62,66
SiO ₂	6,15	6,55	6,3	6,3	6,3	6,3	6,3
CaO	9,17	9,18	9,15	9,15	9,15	9,15	9,15
MgO	1,16	1,13	1,46	1,46	1,46	1,46	1,46
Al ₂ O ₃	0,86	1,17	1,05	1,05	1,05	1,05	1,05
Mn	0,25	0,24	0,29	0,29	0,29	0,29	0,29
P	0,032	0,036	0,035	0,035	0,035	0,035	0,035
S	0,093	0,105	0,104	0,104	0,104	0,104	0,104
C	4,814	5,6	4,3	4,3	4,3	4,3	4,3
Zn	0,009	0,013	0,013	0,013	0,013	0,013	0,013
Na ₂ O	0,075	0,084	0,082	0,082	0,082	0,082	0,082
K ₂ O	0,066	0,091	0,075	0,075	0,075	0,075	0,075

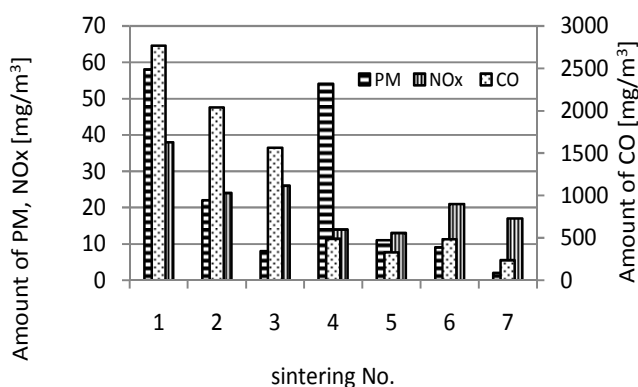
Table 2 Qualitative parameters and chemical composition of agglomerates

	Sinter 1	Sinter 2	Sinter 3	Sinter 4	Sinter 5	Sinter 6	Sinter 7
Size distribution [%]							
> 25 mm	58,39	54,22	56,36	50,68	53,12	62,93	Unsuccessful sintering
10 - 25 mm	18,9	22,05	18,82	20,15	17,87	13,87	
5 - 10 mm	11,41	12,84	12,07	14,97	15,42	10,34	
< 5 mm	9,59	8,95	8,69	13,06	12,35	9,07	
under grate	1,7	1,94	4,06	1,14	1,24	3,79	
Σ	100	100	100	100	100	100	
Chemical composition %							
Fe	54,77	55,15	55,64	55,71	55,71	54,98	Unsuccessful sintering
FeO	12,93	15,23	10,38	10,63	10,78	11,21	
Fe ₂ O ₃	63,99	61,98	68,1	67,88	67,71	66,2	
SiO ₂	8,21	7,87	7,61	7,6	7,58	8,22	
CaO	9,74	9,85	9,38	9,45	9,45	9,58	
MgO	1,8	1,28	1,48	1,37	1,37	1,64	
Al ₂ O ₃	1,03	1,28	1,12	1,1	1,04	1,03	
Mn	0,29	0,24	0,3	0,27	0,35	0,32	
P	0,059	0,042	0,045	0,044	0,044	0,05	
S	0,036	0,038	0,037	0,038	0,038	0,036	
C	0,33	0,63	0,296	0,24	0,174	0,16	
Zn	0,015	0,026	0,018	0,018	0,017	0,018	
Na ₂ O	0,04	0,062	0,056	0,053	0,049	0,048	
K ₂ O	0,023	0,044	0,022	0,018	0,021	0,02	
basicity	1,25	1,22	1,24	1,24	1,25	1,21	

Table 3 Concentrations of particulate matter and gaseous pollutants

Sintering No.	PM mg/m ³	CO mg/m ³	NO _x mg/m ³
1	58	2768	38
2	22	2041,5	24
3	8	1562	26
4	54	490	14
5	11	330	13
6	9	485	21
7	2	237	17

The evaluation of laboratory experiments has shown that the significant increase of particulate matter was observed in the sintering procedure No.1 and No. 4, where the particulate matters (PM) values reached the level of 58 mg/m³ (sintering 1) and 54 mg/m³ (sintering 4), **Fig. 1**.

**Fig.1** Concentrations of pollutants as per sintering

Based on the detailed analysis of all factors that could cause the increase of the particulate matter values, it can be assumed that the increased concentration of particulate matter was caused by under-pressure, which achieved the highest level in case of sintering No. 1 (7.2 kPa). The quantity of particulate matter is significantly affected by the under-pressure level and pelletizing of the mixture, which is moisture-dependent. Other cases of experimental sintering did not show such high quantities of dust emissions due to the under-pressure optimization. This decrease was demonstrated mostly in sintering No. 5, 6 and 7, where under-pressure was lower – at the level of 4.5 kPa. In these cases of experimental sintering the particulate matter concentrations did not reach values higher than 22 mg/m³.

The analyses have shown the connection between the under-pressure value and the CO concentrations in combustion products. In sintering No. 1 the CO emission value of 2768 mg/m³ was reached, and in sintering No. 2 the quantity of CO emissions in the amount of 2041 mg/m³ was measured. In both cases the sintering was performed at a higher under-pressure compared to other sintering procedures. The increased under-pressure accelerates the sintering process, which results in the existence of imperfect combustion of fuel. It means that CO is formed in addition to CO₂ during the combustion process. The presence of CO can be explained by the fact that the fast air flow carries CO produced on the surface of the burning fuel into the cold zone so quickly that the oxidation by atmospheric oxygen is not completed. In addition to other things, the under-pressure change influences also the vertical speed of sintering, (**Fig.2**), which is also

reflected in the total sintering time. The increase of under-pressure from 4.5 kPa to value 7.2 kPa resulted in the decrease of the sintering time from 43 minutes to approximately 30 minutes. The related vertical speed of sintering changed within the range from 8.69 mm/min at under-pressure of 4.5 kPa to 13.35 mm/min at under-pressure of 7.2 kPa.

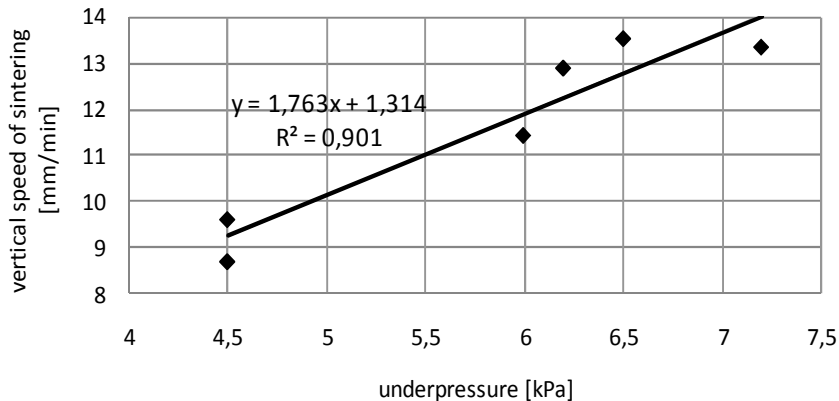


Fig.2 The effect of under-pressure on the vertical speed of sintering

The change of under-pressure during the sintering process was displayed also by the granulometric analysis of agglomerate, which is demonstrated by **Fig.3** showing the correlation between the under-pressure values and the undersize portion of sinter.

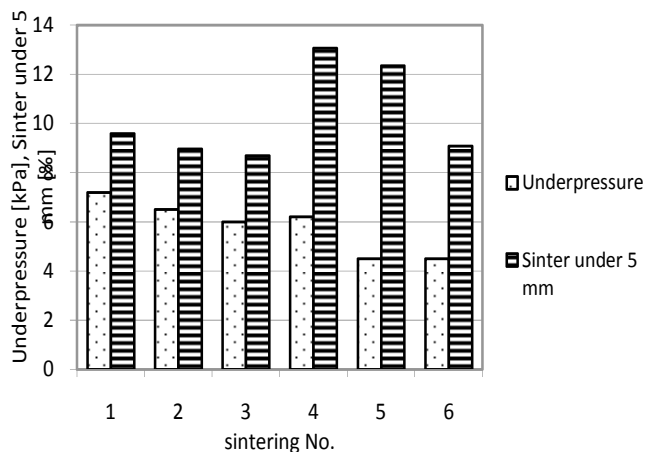


Fig.3 Correlation between under-pressure and sinter quality parameters

It results from the figure that the reduction of under-pressure at the level of 4.5 kPa has a negative impact on one of the agglomerate quality parameters. This impact is demonstrated by the increased values of the undersize portion below 5 mm (especially in case of sintering No. 5). The percentage share of agglomerate below 5 mm in case of sintering No. 5 (under-pressure = 4.5 kPa) was above 12% level. It must be noted that in relation to under-pressure the value of charge permeability must be considered. Sintering No. 4 was performed at under-pressure of 6.2

kPa; however, the highest permeability of mixture ($0.65 \text{ m}^3/\text{min}$) was the indispensable factor in this case. With regard to the complexity of the agglomeration process, the results of the sintering analysis require a comprehensive evaluation of several parameters.

4 Conclusion

The results of the laboratory experiments proved that the change of technological parameters can be used to regulate quantities of pollutants formed. The experiments performed under laboratory conditions proved the influence of the mixture humidity level on the charge permeability and the total sintering time.

The regulation of the sucked air under-pressure and the agglomeration charge humidity affected the overall sintering process, as these parameters resulted in the change of vertical speed of sintering, the overall time of sintering and the quantity of produced particulate matter.

It was established that humidity of the sintered mixture must not drop under 4.5 %. The mixture with the lowest humidity reached the permeability of only $0.25 \text{ m}^3/\text{min}$, while the sintering time increase up to 61 minutes.

Sintering of the mixture with the highest permeability of $0.65 \text{ m}^3/\text{min}$ was characterized by the increased values of particulate matter concentrations in combustion products and simultaneously by the highest quantity of the undersize portion of agglomerate (13.06 % below 5 mm). Also the highest abrasion values $\text{ISO}_{-0,5}$ (8%) were observed. Even though it is a technological requirement to sinter agglomeration mixtures with the highest possible permeability, under certain conditions higher values of sucked air under-pressure may result in the reduction of the produced agglomerate quality (e.g. in case of sintering No. 4). The reduction of particulate matter concentrations can be achieved through decreasing the sucked air quantity. Its results in the drop of the total flow of combustion products, however, the sintering time increases undesirably. The reduction of under-pressure to the level of 4.5 kPa had a positive effect with regard to the environmentally friendly aspects of the production process; however it had a negative impact on the qualitative parameters of agglomerate, as in case of sintering with lower under-pressure levels, the value of agglomerate in the grain class below 5 mm increased.

In connection with the reported results of the laboratory experiments the importance of the optimization of agglomeration charge was proved.

Acknowledgements

Authors are grateful for the support of experimental works by project VEGA 1/0338/09.

References

- [1] J. Kadrnožka: *Global Warming of the Earth*, first ed., VUTIUM, Brno, 2008 (in Czech).
- [2] R. Colin Townsend, M. Begon, L. John: *Fundamentals of Ecology*, first ed., Univerzita Palackého, Olomouc, 2010 (in Czech).
- [3] P. Pustějovská: *Decreasing CO₂ emissions in iron productions*, In.: *Produkcja I zarzadzanie w Hutnictwie*, Sycyzrk, Politechnika Czestochowska, 2006, p. 204 – 207 (in Czech).
- [4] M. Rozpondek, M. Siudek.: *Acta Metallurgica Slovaca*, Vol. 14, 2008, No. 1, p. 119-124.
- [5] T. Ariyama, M. Sato: *ISIJ International*, Vol. 46, 2006, No.12, p. 1736-1744.
- [6] L. Bonte, K. Buttiens, R. Fournelle, G. Merchiers, M. Pieters: *L: La Revue de Métallurgie*, Vol. 98, 2001, No. 4, p. 321-326.
- [7] E. Kasai, Y. Hosotani, T. Kawaguchi, K. Nushiro, T. Aono: *ISIJ International*, Vol. 41, 2001, No. 1, p. 93-97.

- [8] Š. Majerčák, A. Majerčáková: *Blast furnace charge*, first ed., ALFA, Bratislava, 1986.
- [9] D. Debrincat, C.E. Loo, M.F. Hutchens: ISIJ International, Vol. 44, 2004, No.8, p. 1308-1317.
- [10] T. Trišč, P. Ballók, J. Legemza: Acta Metallurgica Slovaca, Vol.1, 1995, No.1, p. 61-67.
- [11] [22.2.2011], <http://facta.junis.ni.ac.rs/walep/walep2001/walep2001-01.pdf>.
- [12] J. Legemza, M. Fröhlichová, R. Findorák, F. Bakaj: Acta Metallurgica Slovaca-Conference, Vol. 1, 2010, p.70-75.
- [13] L. Brož: *Iron Metallurgy*, first ed., SNTL, Alfa, Praha, 1988 (in Czech).
- [14] D. Debrincat, C.E. Loo: ISIJ International, Vol. 47, 2007, No. 5, p. 652-658.
- [15] K. Morioka, S. Inaba, M. Shimizu, K. Ano, T. Sugiyama: ISIJ International, Vol. 40, 2000, No. 3, p. 280-285.