МЕТАЛЛУРГИЯ

SRSTI 53.31.15

https://doi.org/10.48081/FIZV7488

****A. Zhunusov[1] A. Kenzhebekova[2], A. Zhunusova[3]***
Toraighyrov University, Republic of Kazakhstan, Pavlodar

RECYCLING OF METALLURGICAL WASTES

This article presents the results of a research on the recycling of wastes from metallurgical plants in the city of Pavlodar at a steel smelting plant KSP Steel. The pellets were produced with aspiration dust and mixed with steelmaking (white) slag, ferrous sand, scale. The produced pellets were fired at a temperature of 600 °C. The experience with the use of 20 % white slag, 20 % ferrous sand mixed with aspiration dust and 10 % mill scale shows, after burning in a furnace, quite satisfactory strength, which is 80 kg / pellet. The principal possibility of steelmaking using pellets is shown. A positive effect on the recovery process of steelmaking has a carbonaceous reducing agent, which is in the composition of the charge. The pellets are fully capable of partially replacing iron and steel scrap, reducing the cost of metal.

Keywords: aspiration dust, pellets, ferrous sand, slag, steel smelting, induction furnace.

Introduction

At this time, metallurgical plants accumulate a large number of substandard raw materials. Such non-conforming raw materials include dust from aspiration plants, blast dust, screenings of ore materials, i.e. small fraction less than 5 mm.

The use of small fraction in the technological process of production of metals is complicated because of their size, since a significant part of the used fines is carried out by the power-supplying mode of the aggregates and is deposited in dust collectors. Full assimilation of silt charge by furnaces is possible only on condition of its preliminary agglomeration. In a number of metallurgical enterprises such waste is used in the production of sinter, pellets, briquettes [1–2].

At the ferroalloy plants in Kazakhstan there is no such problem, since there are shops for recycling. And almost all the educated fines are used in the production of ferroalloys [3–6].

At the steel mill LLP KSP «Steel» (Pavlodar) the problem of disposal of its own waste has not been solved and is relevant [7]. The plant accumulates a large amount of aspiration dust, metallurgical slags, mill scale and refractory waste.

Materials and research methods

The above wastes are of scientific interest due to the large amount of iron oxide in them, taking into account foreign experience in recycling and reuse [8, 9]. In connection with these scientific issues in the early stages of the research, we took samples of all the available waste at LLP KSP Steel for conducting experiments on making pellets.

Based on this, the technological chain of production and use of pellets as part of the charge for electric smelting is the only acceptable for enterprises of the Pavlodar region, while achieving a high economic result. Given that the average iron content in the above waste is not less than 50 %, and in mill scale more than 70 %.

The chemical composition of all materials used in the research process is shown in Table 1.

Table 1 – The chemical composition of metallurgical wastes, %

Material	$Fe_{общ}$	SiO_2	Al_2O_3	MgO	CaO	S	P	C
Aspiration dust	48,6	6,9	3,1	2,1	11,0	0,16	0,11	8,2
Slag from LF	2,20	21,3	2,4	4,6	55,8	0,96	–	–
Ferrous sand	58,7	6,2–8,2	17-20	0,2	4,5-5,7	0,01	0,01	–
Rolled scale	73,4	3,3	–	–	–	0,01	0,01	0,12

After sampling for the research, all the tested materials were ground to a fraction of 0.1 mm. After grinding, the fractional composition was represented by a fraction of less than –0.1 mm. An adverse effect on pelletizing has a fraction of 0.1–1.6 mm [1]. The test material does not fall within this range.

The process of obtaining pellets consisted of two main sequential operations — the production of raw pellets and the subsequent strengthening by high-temperature roasting. Raw pellets were produced from moistened aspiration dust in a rotating disc pelletizer with a plate diameter of 1000 mm. Researches were carried out in the laboratory of the department "Metallurgy" at the S. Toraighyrov Pavlodar State University. The axis of rotation of the disc pelletizer is inclined to the top by 30–55°. The speed of the disc pelletizer is 16 rpm.

A solution of water with liquid glass in the ratio of 2:1 was used as a binder material.

The results of the experiments are shown in table 2.

Table 2 – The results of pellet production experiments

№ Experiment	Charge composition, % (mass.)					The strength to drop raw (green) pellets, pellet / number dropping	Hardness after burning, kg/pellet	Temperature of burning, °C
	Aspiration dust	Slag from LF	Ferrous sand	Scale	Coke			
1	90	-	-	-	10	3	50	600
2	70	20	-	-	10	5	56	600

3	50	20	10	10	10	7	61	600
4	40	20	20	10	10	10	80	600

From the data of table 2 it can be seen that in the first experiment, aspiration dust with the addition of 10 % solid carbon (coke screenings of 5 mm class) was used as a raw material, the rolling mode was carried out in the normal technological mode. The strength of raw pellets when dropping from a height of 300 mm pellets were not strong enough and crumbled at the 3rd dropping. Raw pellets were burned in a furnace at a temperature of 600 °C. Pellets were strengthened only after firing. It should also be noted that the number of balls formed by 54 % consisted of a fraction of + 5 mm, the rest of the fraction – 5 mm.

In the second experiment, 20 % of the slag of the ladle-furnace furnace (ACP) mixed with aspiration dust was used as raw material. These are slags formed at the end of smelting (final slags) containing a small amount of iron. In electric arc furnaces, during the reduction period under the «final» slag, the content of iron oxides decreases to <1 %, the content of CaO increases to 55–60 %. These slags due to the high content of CaO have a disintegration structure. These slags also do not find application at the plant. Although the chemical composition of these slags are suitable for use in the production of cement. The chemical composition of the ACP slags is given in Table 1. The pellets produced were subjected to natural drying and roasting in a furnace at 600°C. The strength of the pellets after firing reached 56 kg / pellet.

In the third experiment, 20 % ACP slag, 20 % ferrous sand mixed with aspiration dust were used. Ferrous sands - waste alumina production (Pavlodar aluminum plant), formed in the leaching process of bauxite. The granular composition of the ferrous sands does not correspond to the pelletizing regime, therefore we use them in a mixture. The chemical composition of ferrous sands is given in Table 1, from this table a high amount of Fe_2O_3 can be seen.

In the fourth experiment, 20 % slag AKP, 20 % iron sand mixed with aspiration dust, and 10 % mill scale were used as the charge. After firing at a temperature of 600 °C, the strength of the burned pellets was 80 kg / pellet, which fully meets the requirements of electric smelting in accordance with the specifications.

Results and discussion

Resualts of research work have shown the feasibility of working out the technology for the production of pellets from steel-making production waste of KSP Steel. The resulting fine materials at this plant should be used in a mixture with various wastes of metallurgical production in the city of Pavlodar. For example, experience with the use of 20 % slag AKP, 20 % ferrous sand mixed with aspiration dust and 10 % mill scale shows, after burning in a furnace, quite satisfactory strength for use in electric furnaces. The produced pellets can be used both in steel-smelting and in ferroalloy production, as additives or partial replacement of metal shavings or ore material.

Further experiments were devoted to the production of steel in an induction furnace with a partial replacement of scrap metal for the pellets made. When analyzing the results of the chemical composition shown in Table 3, an increase in the percentage of carbon is observed in the experimental swimming trunks with pellets and comparative ones. In 10 experimental meltings of St 3 sp steel, the average carbon content in the use of pellets was 0.19 %, at the same time in 10 comparative melts of these same steel grades, the carbon content in the first sample was 0.12 %. Similarly, there is an increase in carbon content in steel grade St 1 sp.

Table 3 – Characteristics of smelts

Using pellets						Without pellets				
Steel's mark	Smelts quantity	Approximately quantity of pellets on smelts, kg.	Approximately composition acc. To mass, %			Steel's mark	Smelts quantity	Approximately composition acc. To mass, %		
			C	P	S			C	P	S
St 3 sp	10	1,5	0,20	0,006	0,042	St 3 sp	10	0,13	0,002	0,040
St 1 sp	10	1,0	0,19	0,007	0,044	St 1 sp	10	0,11	0,003	0,037
Total	20					Total	20			

In the smelting process, pellets were loaded into pre-melted metal. Melting of the metal produced by the base technology.

The average specific energy consumption for swimming trunks using pellets is higher by 0.52 kW / t than in comparative ones, which is 0.2 %, i.e. The average specific energy consumption is almost at the same level. A slight excess of energy consumption can be attributed to the unstable operation of the GW-MF-25 furnace during the testing period, although according to calculations the power consumption should be less.

Conclusions

In the smelting process, early formation of frothy slags was observed. Foamy slags, as is known [8–20], affect the process of oxidation of solid carbon particles in the pellets with the formation of carbon dioxide, which later, when used in the mixture of pellets, will allow to obtain a significant reduction in specific energy consumption and coke, which was noted on individual heats, where the specific consumption was 480−510 kW in terms of tonne of suitable products.

Thus, the principal possibility of steelmaking using pellets is shown. A positive effect on the recovery process of steelmaking has a carbonaceous reducing agent, which is in the composition of the charge. It should also be noted that the pellets are fully capable of partially replacing iron and steel scrap, significantly reducing the cost of the metal.

REFERENCES

1 **Fernández-González, D., Ruiz-Bustinza, I., Mochón, J., González-Gasca, C., Verdeja, L.F.** Iron ore sintering: Raw materials and granulation Mineral Processing and Extractive Metallurgy Review. – 2017.– Vol. 38(1). – P. 36–46.

2 **Fernández-González, D., Martín-Duarte, R., Ruiz-Bustinza, I., Mochón, J., González-Gasca, C., Verdeja, L.F**. Optimization of sinter plant operating conditions using advanced multivariate statistics : Intelligent data processing. JOM. – 2016.– Vol. 68(8) – P. 2089–2095.

3 **Mekhtiev, A., Shabanov Ye., Issagulov, A., Baissanov, S. et al.** Development of technology of complex aluminum-silicon-chrome alloy with utilization of offgrade raw materials // Metalurgija. – Zagreb, 2015. – Vol. 54. – № 1. – P. 157–160.

4 **Шабанов, Е. Ж., Байсанов , С. О., Исагулов, А. З., Байсанов А. С., Чекимбаев, А.Ф**. Получение комплексного сплава алюмосиликохрома бесшлаковым способом // Российская металлургия (Металлы). – 2014. – № 5. – С. 11–14.

5 **Zhuchkov, V. I., Andreev, N. A., Zayakin, O.V., Ostrovskii, Y. I., Afanas'ev, V.I.** Composition and performance of chromium-bearing ferroalloys Steel in Translation. 2013.

6 **Tolymbekova, L. B., Kim, A. S., Zhunusov, A. K., Babenko, A. A.** Thermal Transformations in Manganese Ores in the Zapadnyi Kamys Deposit and Chare Materials Used to Produse in an Air Flow under Nonisotherval Conditions // Mettallurgist. – New York: Spinger US. – 2013. – Vol. 56. – P. 919–924.

7 **Spanov, S. S., Zhunusov, A.K., Tolymbekova, L.B**. Steel pilot melting at LLP «KSP STEEL» using Ferro-Silica-Aluminum // Mettallurgist. – New York: Spinger US. – 2017. – Vol. 60. Issue 11–12. – P.1149–1154.

8 **Kazuhiro HORII, Naoto TSUTSUMI, Yoshiyuki KITANO, Toshiaki KATO.** Processing and Reusing Technologies for Steelmaking Slag // NIPPON STEEL TECHNICAL REPORT. – №. 104. – 2013. – P. 123–128.

9 **Vlcek J., Tomkova V., Ovcacikova H., Ovcacik F., Topinkova, M. Matejka**.**V.** Slags from steel production: properties and their utilization // Metalurgija. – 2013. – Vol. 52(3). – P. 329–333.

10 **Zhu, T. X, Coley, K. S, Irons, G. A**. Progress in Slag Foaming in Metallurgical Processes // Metallurgical and Materials Transactions B. – 2012. – Vol. 43(4). – P. 751–757.

11 **Ito, K., Fruehan, R. J.** Study on the foaming of CaO-SiO_2-FeO slags : Part I. Foaming parameters and experimental results // Metallurgical Transactions B. – 1989. – Vol. 20(4). – P. 509–514.

12 **Jiang, R, Fruehan, R. J**. Slag foaming in bath smelting // Metallurgical Transactions B. – 1991. – Vol. 22(4). – P. 481–489.

13 **Stadler, SAC. Eksteen, J. J, Aldrich, C.** An experimental investigation of foaming in acidic, high FexO slags. Minerals Engineering. – 2007. – Vol. 20(12). – P.1121–1128.

14 **Zhang, Y., Fruehan, R J.** Effect of the bubble size and chemical reactions on slag foaming. Metallurgical and Materials Transactions B. – 1995. – Vol. 26(4). – P.803–812.

15 **Ghag, S. S., Hayes P. C, Lee H. G**. The Prediction of Gas Residence Times in Foaming CaO-SiO_2-FeO Slags. ISIJ International. 1998. – Vol. 38(11). – P.1216-1224.

16 **Skupien, D. Gaskell, DR**. The surface tensions and foaming behavior of melts in the system CaO-FeO-SiO_2. Metallurgical and Materials Transactions B.– 2000. – Vol. 31(5). – P. 921–925.

17 **Hong, L. Hirasawa, M. Sano, M.** Behavior of Slag Foaming with Reduction of Iron Oxide in Molten Slags by Graphite. ISIJ International. 1998. – Vol. 38(12). – P.1339–1345.

18 **Lotun, D., Pilon L**. Physical Modeling of Slag Foaming for Various Operating Conditions and Slag Compositions. ISIJ International. – 2005. – Vol. 45(6). – P. 835–840.

19 **Krishnan, S. S. Balasubramanian, N**. Metallurgical Production Plant–Energy and Environment // Treatise on Process Metallurgy : Industrial Processes Pages. – 2014. – Vol. 3. – P.1193–1247.

20 **Anderson, C. G**. Pyrometallurgy // Reference Module in Materials Science and Materials Engineering. – 2016.

REFERENCES

1 **Fernández-González, D., Ruiz-Bustinza, I., Mochón, J., González-Gasca, C., Verdeja, L. F.** Iron ore sintering: Raw materials and granulation Mineral Processing and Extractive Metallurgy Review. – 2017.– Vol. 38(1). – P. 36–46.

2 **Fernández-González, D., Martín-Duarte, R., Ruiz-Bustinza, I., Mochón, J., González-Gasca, C., Verdeja, L. F**. Optimization of sinter plant operating conditions using advanced multivariate statistics : Intelligent data processing. JOM. – 2016.– Vol. 68(8) – P. 2089–2095.

3 **Mekhtiev, A., Shabanov Ye., Issagulov, A., Baissanov, S**. **et al.** Development of technology of complex aluminum-silicon-chrome alloy with utilization of offgrade raw materials // Metalurgija. – Zagreb, 2015. – Vol. 54. – № 1. – P. 157–160.

4 **Шабанов, Е. Ж., Байсанов, С. О., Исагулов, А. З., Байсанов А. С., Чекимбаев, А.Ф**. Получение комплексного сплава алюмосиликохрома бесшлаковым способом // Российская металлургия (Металлы). – 2014. – № 5. – С. 11–14.

5 **Zhuchkov, V. I., Andreev, N. A., Zayakin, O. V., Ostrovskii, Y. I., Afanas'ev, V. I.** Composition and performance of chromium-bearing ferroalloys Steel in Translation. 2013.

6 **Tolymbekova, L. B., Kim, A. S., Zhunusov, A. K., Babenko, A. A.** Thermal Transformations in Manganese Ores in the Zapadnyi Kamys Deposit and Chare Materials Used to Produse in an Air Flow under Nonisotherval Conditions // Mettallurgist. – New York: Spinger US. – 2013. – Vol. 56. – P. 919–924.

7 **Spanov, S. S., Zhunusov, A.K., Tolymbekova, L.B**. Steel pilot melting at LLP «KSP STEEL» using Ferro-Silica-Aluminum // Mettallurgist. – New York: Spinger US. – 2017. – Vol. 60. Issue 11–12. – P.1149–1154.

8 **Kazuhiro HORII, Naoto TSUTSUMI, Yoshiyuki KITANO, Toshiaki KATO.** Processing and Reusing Technologies for Steelmaking Slag // NIPPON STEEL TECHNICAL REPORT. – №. 104. – 2013. – P. 123–128.

9 **Vlcek J., Tomkova V., Ovcacikova H., Ovcacik F., Topinkova, M. Matejka**.V. Slags from steel production: properties and their utilization // Metalurgija. – 2013. – Vol. 52(3). – P. 329–333.

10 **Zhu, T. X, Coley, K. S, Irons, G. A**. Progress in Slag Foaming in Metallurgical Processes // Metallurgical and Materials Transactions B. – 2012. – Vol. 43(4). – P. 751–757.

11 **Ito, K., Fruehan, R. J.** Study on the foaming of CaO-SiO_2-FeO slags : Part I. Foaming parameters and experimental results // Metallurgical Transactions B. – 1989. – Vol. 20(4). – P. 509–514.

12 **Jiang, R, Fruehan, R. J**. Slag foaming in bath smelting // Metallurgical Transactions B. – 1991. – Vol. 22(4). – P. 481–489.

13 **Stadler, SAC. Eksteen, J. J, Aldrich, C.** An experimental investigation of foaming in acidic, high FexO slags. Minerals Engineering. – 2007. – Vol. 20(12). – P.1121–1128.

14 **Zhang, Y., Fruehan, R J.** Effect of the bubble size and chemical reactions on slag foaming. Metallurgical and Materials Transactions B. – 1995. – Vol. 26(4). – P.803–812.

15 **Ghag, S. S., Hayes P. C, Lee H. G**. The Prediction of Gas Residence Times in Foaming CaO-SiO_2-FeO Slags. ISIJ International. 1998. – Vol. 38(11). – P.1216-1224.

16 **Skupien, D. Gaskell, DR**. The surface tensions and foaming behavior of melts in the system CaO-FeO-SiO_2. Metallurgical and Materials Transactions B.– 2000. – Vol. 31(5). – P. 921–925.

17 **Hong, L. Hirasawa, M. Sano, M.** Behavior of Slag Foaming with Reduction of Iron Oxide in Molten Slags by Graphite. ISIJ International. 1998. – Vol. 38(12). – P.1339–1345.

18 **Lotun, D., Pilon L**. Physical Modeling of Slag Foaming for Various Operating Conditions and Slag Compositions. ISIJ International. – 2005. – Vol. 45(6). – P. 835–840.

19 **Krishnan, S. S. Balasubramanian, N**. Metallurgical Production Plant–Energy and Environment // Treatise on Process Metallurgy : Industrial Processes Pages. – 2014. – Vol. 3. – P.1193–1247

20 **Anderson, C. G**. Pyrometallurgy // Reference Module in Materials Science and Materials Engineering. – 2016.

Material received on 17.12.21.

***А. Жунусов[1], А. Кенжебекова[2], А. Жунусова[3]**
[1,2,3]Торайгыров университеті, Қазақстан Республикасы, Павлодар қ.
Материал баспаға 17.12.21 түсті.

МЕТАЛЛУРГИЯЛЫҚ ҚАЛДЫҚТАРДЫ ҚАЙТА ӨҢДЕУ

Бұл мақалада Павлодар қ. металлургиялық зауыты «KSP Steel» ЖШС болат балқыту зауытының қалдықтарын қайта өңдеуді зерттеу нәтижелері келтіріледі. Шекемтастар аспирациялық шаңмен және болат балқытатын (ақ) қожбен, темірлі құммен, от қабыршақты қоспамен өндірілді. Алынған шекемтастар 600 °С. температурада күйдіру сатысынан өтті. Ақ қождың 20 %, аспирациялық шаңмен араласқан темір құмдардың 20 % және илем отқабыршығының 10 % қолдану тәжірибесі пештегі күйдіруден кейін 80 кг/шекемтасқа тең болатын қанағаттанарлық беріктікті көрсетеді.

Шекемтастарды қолдана отырып, болатты балқытудың негізгі мүмкіндігі көрсетілген. Болатты балқытудың қалпына келтіру процесіне шихта құрамындағы көміртекті тотықсыздандырғыш оң әсер етеді. Шекемтастар шойын мен болат сынықтарын ішінара алмастыра алады, металдың өзіндік құнын төмендетеді.

Кілтті сөздер: аспирациялық шаң, шекемтастар, темірлі құм, қож, болат балқыту, индукциялық пеш.

***А. Жунусов[1], А. Кенжебекова[2], А. Жунусова[3]**
[1,2,3]Торайгыров Университет, Республика Казахстан, г. Павлодар.
Материал поступил в редакцию 17.12.21.

ПЕРЕРАБОТКА МЕТАЛЛУРГИЧЕСКИХ ОТХОДОВ

В данной статье приводятся результаты исследования переработки отходов металлургических заводов г. Павлодара сталеплавильного завода ТОО KSP «Steel». Окатыши производились с аспирационной пылью и в смеси со сталеплавильным (белым) шлаком, железистым песком, окалиной. Полученные окатыши проходили стадию обжига при температуре 600 °С. Опыт с использованием 20 % белого шлака, 20 % железистых песков в смеси с аспирационной пылью и 10 % прокатной окалины показывает после обжига в печи вполне удовлетворительную прочность, которая равна 80 кг/окатыш. Показана принципиальная возможность выплавки стали с использованием окатышей. Положительное влияние на восстановительный процесс выплавки стали оказывает углеродистый восстановитель, находящийся в составе шихты. Окатыши вполне способны частично заменить чугун и стальной лом, снизив себестоимость металла.

Ключевые слова: аспирационная пыль, окатыши, железистый песок, шлак, выплавка стали, индукционная печь.

Теруге 17.12.21 ж. жіберілді. Басуға 27.12.21 ж. қол қойылды.
Электрондық баспа
5,07 Mb RAM
Шартты баспа табағы 9,15 Таралымы 300 дана. Бағасы келісім бойынша.
Компьютерде беттеген: Е. Е. Калихан
Корректор: А. Р. Омарова

Тапсырыс № 3875

«Toraighyrov University» баспасынан басылып шығарылған
Торайғыров университеті
140008, Павлодар қ., Ломов көш., 64, 137 каб.

«Toraighyrov University» баспасы
Торайғыров университеті
140008, Павлодар қ., Ломов к., 64, 137 каб.
67-36-69

e-mail: kereku@tou.edu.kz
nitk.tou.edu.kz