Conference Paper

Using of Enriched Air Blast While Operation of Shaft Furnaces at LLC "Mednogorsk Copper-Sulfur Plant"

Ibragimov A.F.[1], Iskhakov I.I.[1], Skopov G.V.[2,3,4], and Kirichenko A.N.[1]

[1]LLC "Mednogorsk Copper-Sulfur Plant", Mednogorsk, Russia
[2]"UMMC-Holding" Corp., Verkhnyaya Pyshma, Sverdlovsk region, Russia
[3]Ural Federal University named after B.N. Yeltsin, Ekaterinburg, Russia
[4]Non-State Higher Education Institution "UMMC Technical University", Verkhnyaya Pyshma, Sverdlovsk region, Russia

Abstract

In this article we consider the practices of blast smelting of copper-bearing charge with oxygen enriched air blast at Mednogorsk Copper-Sulfur Plant. The degree of air blast enrichment with oxygen has been increased from 30% to 36%, and productivity has raised by 20.1%. The copper content in matte has made up 33.0-35.3%, in dump slag – to 0.5% Cu. We have provided the mass and heat balances of the smelting. We have demonstrated the influence of air blast oxygen enrichment degree on productivity of blast smelting, solid fuel consumption, contents and quantity of smelting products.

Keywords: blast smelting, air blast, oxygen enriched, enrichment degree, furnace capacity, specific smelting rate, matte, anthracite.

Corresponding Author:
Skopov G.V.
skopov@ugmk.com

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In spite of the fact that the key priority directions of metallurgy development in XXI century are the technologies based on oxidizing smelting of polymetallic concentrates, suspended or in fluid bath [1], at some enterprises [2], including LLC "Mednogorsk Copper-Sulfur Plant", the blast smelting is still high on agenda.

Smelting of agglomerated sulfide charge in shaft furnaces has a number of competitive advantages, such as high specific capacity, high heat efficiency, easy furnace maintenance and process control, comparatively low temperature of exhaust gases, low consumption of refractory materials due to coffered walls using.

Along with that, blast furnace has a number of significant weaknesses, which in up-to-date conditions invalidate its advantages: necessity of preliminary charge agglomeration, periodicity of charge loading, low degree of air blast oxygen enrichment, comparatively low-grade matte as a result of smelting, high inertia during process control.

Mednogorsk Copper-Sulfur Plant has unique experience of shaft furnace operation and various types of smelting performed in such furnaces. At different times they applied the technologies of copper-sulfur smelting by method of "Orkle" [2], concentrating smelting, autogenous blast smelting of briquetted charge [3] and have introduced the technology of autogenous blast smelting of copper concentrate pellets and technology of smelting the clinker from zinc production [4, 5].

Originally, the autogenous blast smelting process was elaborated for improving the applicable at that moment technology of high-sulfur ore smelting (copper-sulfur) with air blast oxygen enriched to 28-32% and with copper content in copper matte of 20-30% and in slag – 0.25-0.35%. With that, the major part of sulfur was extracted in elementary form after complex gas purification, catalysis and condensation. The technology, as it stands, has not been introduced, as far as the development of Blyavinsky mine has been finished, and the ore from this mine was the most suitable and met the requirements of copper sulfur-smelting, because it did not almost contained zinc and arsenic.

Due to absence of other suitable ores the acute need to start the smelting of copper concentrate with high content of zinc and arsenic admixtures from Gaisky Concentrator (Gaisky GOK) has arisen. For this purpose it was necessary to meet two challenges: to set up concentrate briquetting and blast smelting of briquettes with fluxes resulting in sulfur recovery into process gas in the form of dioxide suitable for treatment at sulfur acid production.

Starting from 1986 after putting the oxygen plant with the capacity of 5 ths. nm^3 of industrial oxygen per hour into operation the major part of sulfide raw materials supplied to Mednogorsk Copper-Sulfur Plant has been briquetted, pelletized and processed in shaft furnaces at the former concentrating smelting site with oxygen enriched air blast.

As for charge briquetting for further smelting we have taken into account the experience of the plants "Legnitsa" (Poland), "Gloguv-I" (Poland) and "Mansfeld Mining and Metallurgical Plant" named after Wilhelm Pieck (Germany) using a high pressure grinding roller and sulfite-cellulose alkali liquor as a binder.

Peculiar conditions of sulfide oxidation in shaft furnace create close contact of these sulfides with quartz skull in the tuyere area, what prevents iron overoxidation and allows providing the magnetite mass fraction in dump slag less than 3-5%. Introduction of oxygen enriched air blast allowed treating 85-90% of primary sulfide raw materials in two shaft furnaces at the former concentrating smelting site [3, 4].

In 1988-1990ss the specialists of the plant jointly with the institute "Unipromed" have elaborated an original technology of processing the copper concentrate from Gaisky Concentrator (Gaisky GOK) into high-strength pellets by hydrothermal hardening in horizontal autoclaves with synthesis of hydrosilicate bonder [5].

Finished pellets with the diameter of 15-18 mm and moisture level of 0.8-5.0% had the compressive strength of 600-890 N and strength for throwing off from the height of 2 m on a metal plate – 9-13 times. Replacement of briquettes in the shaft furnace charge for pellets has positively influenced the uniformity of air blast arrangement in the furnace and allowed increasing the capacity by 32-36% (rel.) with constant air blast oxygen enrichment to 26–29% (vol.). Temperature of exhaust gases reduced by 80-100 ^{0}C, copper content in matte increased by 8-10 %, dust entrainment decreased by a factor of 1.4-1.6.

Specific charge smelting rate made up 66-68 t/m^{2}day, including pellets 54 t/m^{2}day, with air blast consumption of 25 – 28 ths. m^3/h and oxygen – 2.5 – 3.0 ths. m^3/h. Copper content: in matte 32.0 – 37.2%, in slag 0.27 – 0.37% (with content of SiO_2 35-37%, CaO 11-12%). Dust entrainment level reached 3.4% of charge mass. Average composition of exhaust gases, volume %: 9.0 SO_2, 10.0 O_2, 11.0 CO_2, 0.1-0.2 COS, 0.1-0.2 CS_2.

Special attention from the view point of shaft furnace using should be drawn to elaborated and introduced by Mednogorsk Plant technology of processing the clinker from zinc production, which due to polydispersity and complex material composition (metallic iron 21-35%, hydrogen 20-25 % linked with hard-melting oxide phases and low sulfur content) falls into the category of refractory materials. Most of existing methods of clinker smelting into matte proposed putting the high-sulfur materials – sulfidizers into the charge (ore, pyritic or copper concentrate), what complicated further sulfur utilization.

Creation of a new technology of clinker processing in shaft furnaces was targeted at sulfidizer removal from the charge and efficient combining the sites of sufilde and low-sulfur raw materials processing at one and the same copper smelter.

Based on performed complex of R&D works and experimental-industrial trials, the theory of clinker smelting without sulfidizer has been elaborated, and the sequence of clinker components has been determined: coke breeze → carbon dissolved in iron → metallic iron → sulfides. Necessity of return converter slag introduction into charge in ratio of 1:1 to clinker has been demonstrated for using the magnetite contained in slag as a reagent for oxidation and slagging the clinker metallic iron [6].

Currently, at Mednogorsk Copper-Sulfur Plant the following process flow of blister copper production is used. It includes the following operations:

Briquetting of starting raw materials → blast smelting → combined smelting-converting → converting.

This process flow provides preliminary agglomeration of starting copper-bearing raw materials and subsequent briquetting. Then briquettes are smelted together with fluxes and return converter slag in shaft furnaces, what provides copper matte and dump slag. Copper matte is sent to Peirce-Smith horizontal converters and to the plant of combined smelting and converting, where some part of briquette screenings are smelted. The final product of converting is blister copper, and slag from the converter and from the plant of combined smelting and converting is return slag, so after cooling it is fed to shaft furnaces. Some part of starting copper-bearing raw materials is processed at the plant of combined smelting and converting without preliminary agglomeration, then high-grade matte from the plant of combined smelting and converting is fed for converting.

Facilities of Mednogorsk Copper-Sulfur Plant existed before 2016 allowed using oxygen-air mixture as air blast for shaft smelting in terms of process oxygen availability with rate of enrichment to 30 - 31%. Oxygen consumption per each of two shaft furnaces made up, in average, 2500 nm^3/h, air blast consumption - to 17000 nm^3/h. At that, one furnace smelted 680-710 t of charge per day with the specific smelting rate of 59.0 – 62.2 t/m^2*d.

Sulfide briquettes (copper concentrates from PJSC “Gaisky GOK” and CJSC “Buribaevsky GOK” as well as clinker from OJSC “Elektrozinc”), reverts (converter and smelting/converting furnaces slag), quartz, limestone, non-agglomerated clinker and fuel (anthracite, Grade AO, produced by JSC Central Concentrator “Gukovskaya”) were supplied for smelting. Sulfide briquette in the charge was 45.0-50.0%, non-agglomerated clinker was about 3.5%, anthracite consumption was about 3.0-3.6% of the charge. Table 1 shows material balance calculation of blast smelting based on main components for this period of work.

Table 1: Material balance of blast smelting

Description	weight		Cu	Fe	S	C	Others
	t	%	%	%	%	%	%
Charge							
Sulfide briquette	350.00	22.27	14.00	30.94	33.80	1.50	19.75
Clinker	20.00	1.27	2.07	21.90	6.00	22.00	48.04
Quartz flux	51.90	3.30		1.30			98.70
Limestone	37.60	2.39		0.40			99.60
Reverts	232.22	14.77	2.25	44.00	1.12		52.64
Fuel	25.10	1.60		0.98	0.51	81.64	16.87
Blast air	473.43	30.12					100.00
Blast process oxygen	82.23	5.23					100.00
Air inflow through charging	290.38	18.47					100.00
Charge moisture	8.98	0.57					100.00
Total	1, 571.83	100					
Product							
Matte	177.19	11.27	28.22	42.46	24.14		5.18
Slag	385.75	24.54	0.50	33.67	2.22		63.61
Dust	33.88	2.16	8.06	31.87	10.82		49.25
Gas	975.01	62.03			6.90	3.09	90.01
Total	1, 571.83	100					

In November 2016, the first stage of a new oxygen station operating on the principle of vacuum short-cycle adsorption (VShCA) with a production rate of 5,833 Nm3/h was put into operation at MMSP, LLC. It led to improvement of production efficiency at MMSP LLC by using an oxygen-air mixture with a higher oxygen content as a blast for shaft furnaces and smelting/converting furnaces.

The oxygen consumption of each blast furnace has been increased stage-by-stage: initially, up to 2,700–3,000 Nm3/h with an air blast consumption of 15,200–16,400 Nm3/h and average oxygen enrichment rate of 32.5%. Moreover, blast furnace capacity averaged 730 tons of charge per day, as well as anthracite consumption of 2.0-2.4% of the charge.

Further attempts to increase oxygen consumption led to raise of disturbances in the stable furnace operation due to formation of local purges and scull on the furnace walls and roof. Temperature rise of the exhaust gases increased the load of the dust/gas cleaning facilities and draft equipment and decreased the thermal efficiency of the unit.

For the stable operation of the furnace, special measures had to be taken, i.e. once-trough charges of anthracite, as well as a special slag charge (converter slag + anthracite) at reduced feed rate, which led to loss of furnace capacity and increase in fuel consumption. Leakage of weld seams has become more frequent in the area of flange joints of evaporative cooling elements, as well as around the tuyere tubes inside the furnace, due to significant local temperature differences, which occur because of increased fuel consumption.

The main reasons for that are the low briquette strength and improper charge recipe for blast furnaces. Correction actions allowed considering the use of an oxygen-air mixture with an oxygen flow rate max.3,800-4,000 Nm3/h and a blast enrichment rate max. 36.6%.

The average specific smelting rate of the charge with an increased oxygen consumption was 72.1 t/m2 per day and, in particular periods, reached 78.4 t/m2* per day with max. 35.3% of copper in matte (Figures 1&2). At the same time, deeper and faster oxidation of sulfides has enhanced heat release per unit time, which allowed reducing significantly the consumption of anthracite avg. to 1.1-1.3% of the charge (Figure 3) and increasing the content of sulfur dioxide in the exhaust gases of blast furnaces (Figure 4).

As a result of increased oxygen consumption and oxygen-air mixture enrichment degree, capacity of each furnace achieved on average 850 tons of charge per day. Sulfide briquette percentage in the charge was 48.0–50.0%, zinc clinker - 8.0%, and anthracite consumption was in the range of 1.1–1.4% of the charge. Matte and dump slag with copper content of 31.0–35.3% and 0.48–0.50%, respectively, were produced.

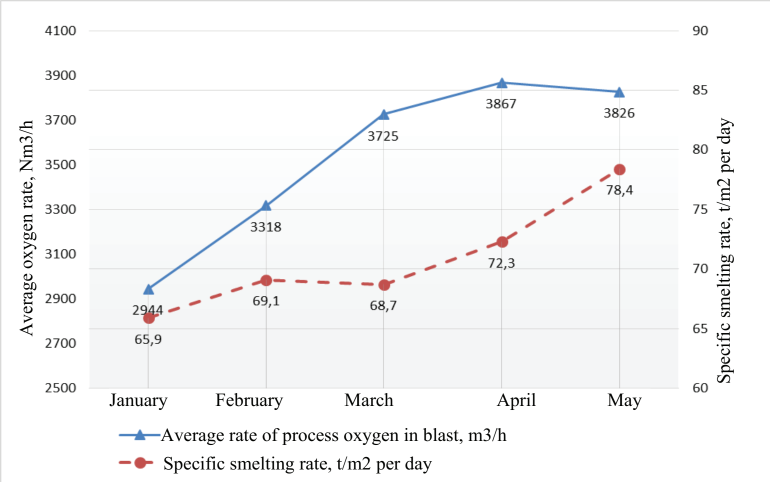

Figure 1: Specific smelting rate of blast furnaces

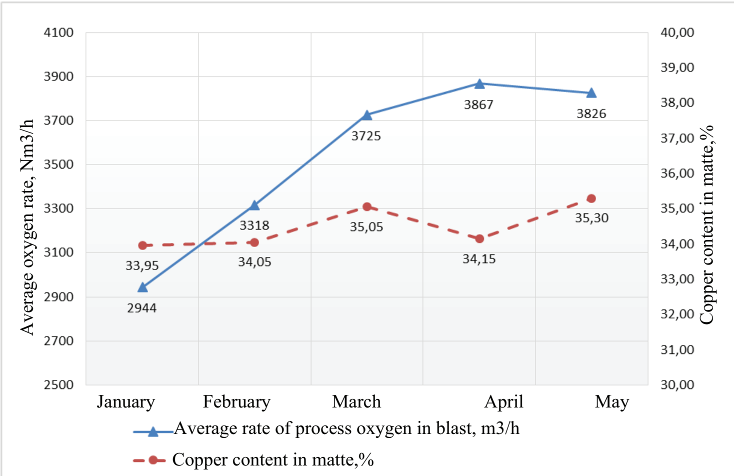

Figure 2: Copper content in matte

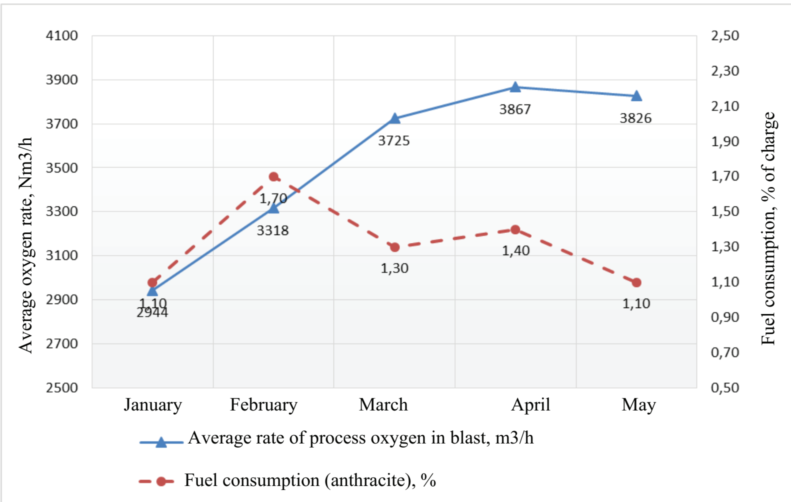

Figure 3: Fuel consumption

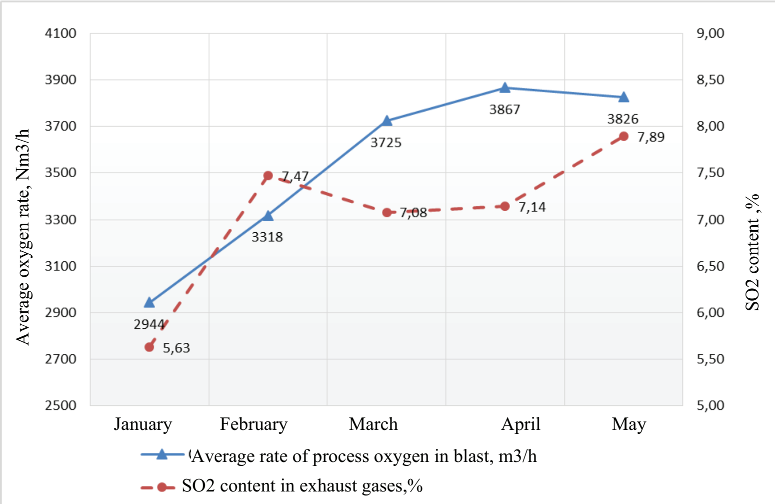

Figure 4: Sulfur dioxide content in exhaust gases

Table 2 shows the calculation of the material balance of blast smelting for this period of work.

The above results of blast furnaces operation before and after increasing the blast oxygen have led to the following conclusions.

• The blast enrichment has enhanced blast furnaces capacity by 20.1% by the charge.

• Fuel consumption has been reduced from 3.6% to 1.3% due to acceleration of sulfide oxidation;

• The degree of desulfurization has increased, which led to growth of copper content in the matte and concentration of sulfur dioxide in the exhaust gases.

The calculation of heat balance (Table 3) shows that in both periods there is an excess heat (max. 2%). Some redistribution of heat occurs in the second period. Thus, while in the first period there was heat loss with exhaust gases, which amounted to 37.40% of the total heat losses, but when using an oxygen-air mixture with the larger amount of oxygen, the 40.6% of heat loss with slag and 34.63% of heat loss with gases were achieved.

1. Conclusions

1. For the first time, the possibility of blast furnace operation mainly using sulfide raw materials with blast oxygen enriched up to 36.6% (vol.) was presented in the course of pilot tests.

2. As a result of smelting enhancement at MMSP LLC, charge capacity of the blast furnace has been improved by more than 20%, while actual fuel (anthracite) consumption has been reduced to 1.3% (abs.) of the charge.

Table 2: Material balance of shaft smelting

Description	weight		Cu	Fe	S	C	Others
	t	%	%	%	%	%	%
Feed							
Sulfide briquette	419.00	24.37	14.00	30.94	33.80	1.50	19.75
Clinker	58.00	3.37	2.07	21.90	6.00	22.00	48.04
Quartz flux	73.05	4.25		1.30			98.70
Limestone	46.80	2.72		0.40			99.60
Reverts	233.74	13.59	2.25	44.00	1.12		52.64
Fuel	10.90	0.63		0.98	0.51	81.64	16.87
	830.59						
Blast air	445.10	25.88					100.00
Blast process oxygen	125.58	7.30					100.00
Air inflow through charging	295.60	17.19					100.00
Charge moisture	11.76	0.68					100.00
Total	1,719.53	100					
Product							
Matte	180.85	10.52	32.89	38.11	22.88		6.12
Slag	482.15	28.04	0.49	34.26	2.15		63.10
Dust	39.96	2.32	8.15	30.83	11.09		49.93
Gas	1,016.56	59.12			9.01	2.75	88.24
Total	1,719.53	100					

Table 3: Heat balance of blast furnace

Balance item	Period of 2016		Period of 2018	
	kcal.	%	kcal.	%
Energy input				
Sensible heat of charge	3,505.89	1.00	4,189.45	1.05
Sensible heat of fuel	251.00	0.07	109.00	0.03
Sensible heat of blast air	3,408.67	0.97	3,204.71	0.80
Sensible heat of blast oxygen	542.72	0.15	828.85	0.21
Chemical heat	344,635.16	97.81	392,488.44	97.92
Total	352,343.45	100.00	400,820.45	100.00
Energy output				
Matte heat	30,565.69	8.67	31,196.77	7.78
Slag heat	130,190.57	36.95	162,726.23	40.60
Gas heat	131,791.47	37.40	138,784.60	34.63
Dust heat	4,099.54	1.16	4,835.59	1.21
Heat to atmosphere	50,430.04	14.31	57,382.34	14.32
Heat excess	5,266.14	1.49	5,894.93	1.47
Total	352,343.45	100.00	400,820.45	100.00

The following people have been directly involved:

T.V. Aburkin – Deputy Chief Production Engineer

S. A. Lepin – Head of the Smelting Plant, MMSP LLC.

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