UDC 66.041.37:666.92

Efficiency of Using Top Gas in Opposite-Flow Lime-Burning Furnace

M. V. Gubinsky, S. S. Fedorov, S. N. Foris`, A. V. Agadzhanyan

National Metallurgical Academy of Ukraine
4 Gagarin Ave., Dnipropetrovsk, 49600, Ukraine

Due to high cost of primary energy resources it is urgent to work out the alternative methods of furnace heating. Performance parameters of shaft lime-burning furnace with daily output 200 tons are researched at partial substitution of natural gas by top gas. Effect of top gas on lateral and peripheral burners during supply is studied.

Keywords: OPPOSITE-FLOW LIME-BURNING FURNACE, TOP GAS, MATHEMATICAL MODEL, CALCINATIONS DEGREE, SPECIFIC FUEL CONSUMPTION, SAVING

Introduction

Iron and steel industry is the largest producer and consumer of technological lime carbonate. The basic lime consumers are agglomeration, blast-furnace and steel-making processes. Consumption of metallurgical lime is 25-30 % at the annual level of lime carbonate production in Ukraine 15-18 million tons [1].

Lime production refers to power-intensive processes. The considerable part of lime is produced in shaft furnaces which can be explained by simplicity of furnace design, low investment costs and high thermal efficiency of such units [1, 2]. As a rule, cost intensive natural gas is used at iron & steel plants in the shaft furnaces. In average, the specific charge of natural gas per one ton of active lime is 200-220 kg coal equivalent. Thus, the share of costs for fuel in the cost price of lime is approximately 50-60 % [3]. Study of supply-demand balance of certain Ukrainian iron & steel plants shows the tendency of blast-furnace slag output raise which is related, first of all, to increase in volumes of metal product output. Thereupon, the issue of purchased fuel consumption reduction at iron & steel plants due to using own energy resources is urgent. Partial or complete top gas heating can be one of possible solutions of this problem.

According to expert estimations [4], it is possible to heat shaft furnaces by natural-top mixture with combustion heat approximately 10 MJ/m^3. In this case, specific saving of natural gas is about 25 kg coal equivalent/t of lime. The further increase in top gas share will lead to growth of heat leakage with exhaust gas. However, the issue of rock gas substitution needs more detailed study as change of fuel type will inevitably affect gas-dynamic operating mode and operating characteristics of the furnace.

The task of calculation-theoretical research of possible rock gas substitution in shaft furnaces is set and such substitution efficiency is estimated.

Methodology

The subject of research is a shaft counter-flow furnace [2]. The design of this furnace is illustrated in **Figure 1**. The furnace represents a vertical cylindrical freeboard. Lime charging is carried out from above with the skip hoist, discharging - in the furnace base. The working space of the furnace consists of three technological zones: lime heating zone, burning zone and lime cooling zone, in which air is heated up. The fuel is supplied through two tiers of side burners and the central burner (core). The part of smoke gases goes on recirculation to the central burner. The key technical characteristics are presented in **Table 1**.Top gas effect on operation of shaft lime-burning furnace is investigated with the use of plant mathematical model. The mathematical model considers gas dynamics and heat transfer in the shaft lime-burning furnace with the central and peripheral input of gas fuel [5].

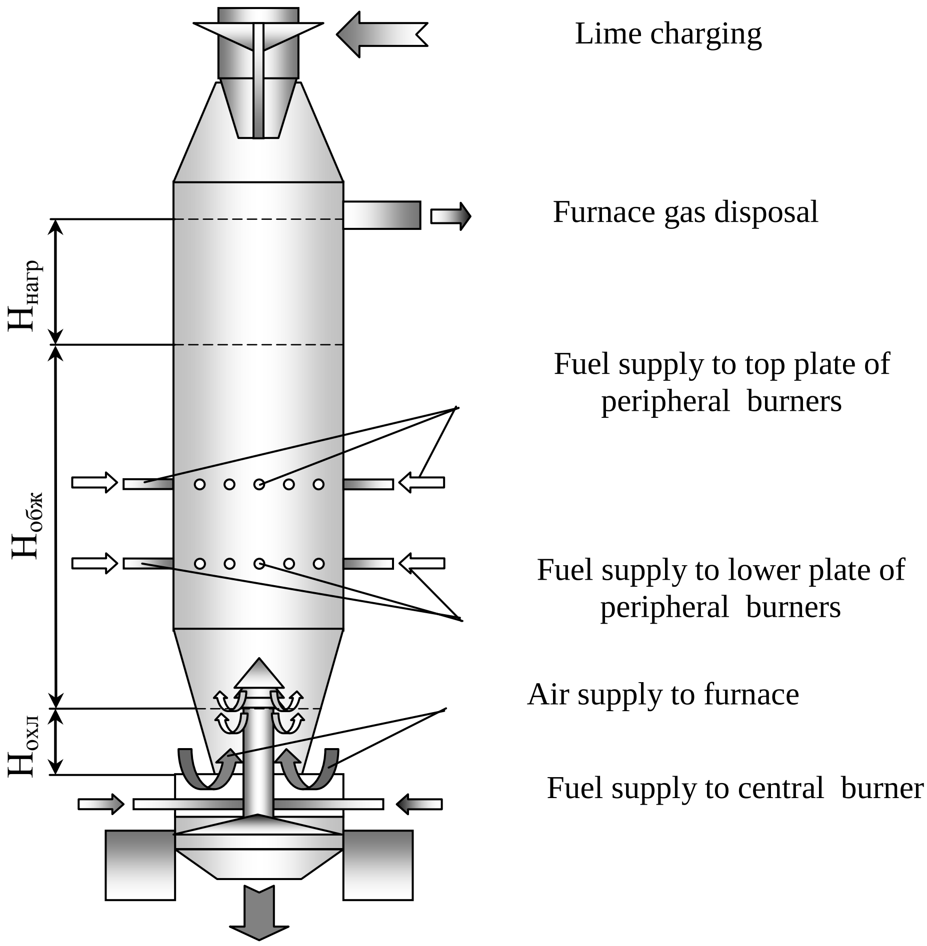


Figure 1. Design of shaft lime-burning furnace on gas fuel: H_{heat} - altitude of lime heating zone; H_{calc} - altitude of lime calcination zone; H_{cool} - altitude of lime cooling zone

Table 1. The key technical characteristics of shaft lime-burning furnace with capacity 200 t/day

Parameter	Value
Furnace operating height, m	18
Shaft diameter, m	4.3
Layout level of central burner in relation to outloading table, m	2
Layout level of lower plate of peripheral burners in relation to outloading table, m	6
Layout level of top plate of peripheral burners in relation to outloading table, m	8

Results and Discussion

According to estimations, the maximum allowed volume fraction of top gas in natural-top mixture is approximately r_{tg} = 0.8 (**Figure 2**). Thus, the heat of combustion of such mixture is 9.4 MJ/m^3. The optimum furnace conditions on the rock gas we accepted as the base (**Table 2**): the total charge of rock gas 1100 m^3/h; air-flow rate on the central burner 1000 m^3/h; air-flow rate in the bottom of furnace 9500 m^3/h; stone rate 314 t/h; calcination degree 85 % [6].

The results of investigation of top gas effect on the blast-furnace operation are presented in **Table 2** and **Figures 2-3**. According to obtained data, the furnace behaves in a different way depending on top gas supply. So, with other things being equal, the increase of top gas charge (r_{tg}^{c} = 0-0.8) on the central burner leads to some decline of blast-furnace operation. Gas temperature in the central zone drops and this promotes to deterioration of calcination qaulity (**Figure 3**). Thus, the fuel incomplete combustion decreases, however heat leakage with exhaust gas grow. At top gas supply (r_{tg}^{p} = 0-0.8) on peripheral burners the temperature in the near-wall layer decreases in a similar way. However, the operation of side burners is characterized by excess of oxidizing agent.

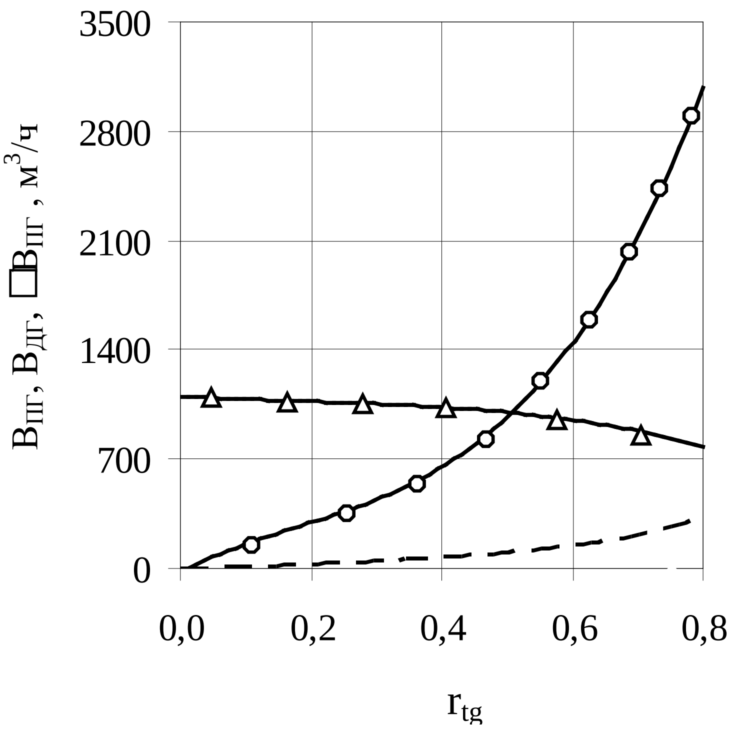
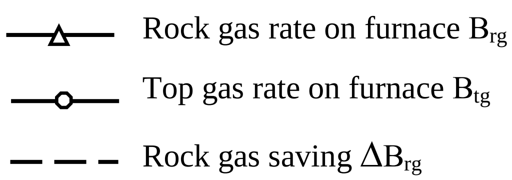


Figure 2. Dependence of fuel rate on amount of top gas in the mixture:



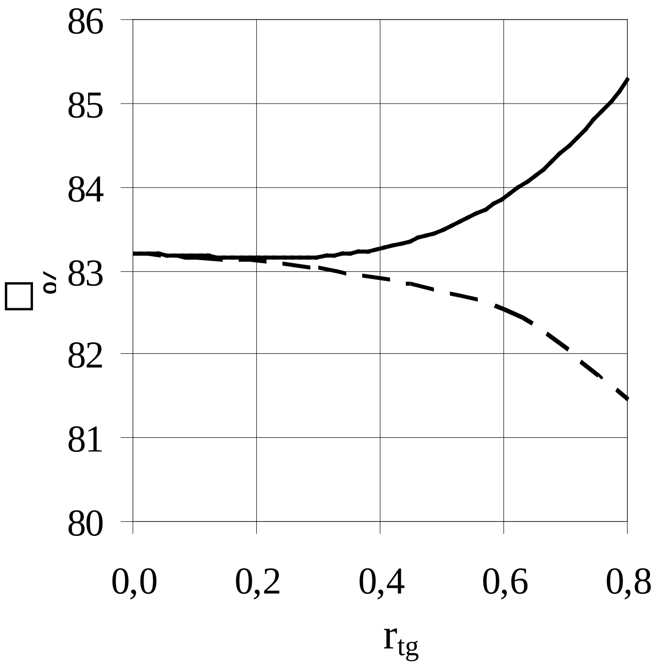


Figure 3. Change of calcination degree σ depending on top gas fraction in the mixture r_{tg}:

TG on peripheral burners

TG on central burner

Table 2. Parameters of blast-furnace operation using top gas

Parameter	Optimum operation mode using rock gas	Blast-furnace operation with top gas supply		
		central burner	peripheral burners	all burners
Volume ratio of top gas in the mixture, r_{tg}	-	0.8	0.8	0.8
Top gas charge, m^3/h:				
- on central burner	-	1187	0	1187
- on peripheral burners	-	0	1922	1922
Rock gas charge, m^3/h:				
- total on furnace	1100	977	901	778
- on central burner	420	297	420	297
- on peripheral burners	680	680	481	481
Rock gas saving, m^3/h	-	123	199	322
Stone rate, t/day	314	320	320	320
Calcination degree, %	85.0	81.6	86.3	84.5
Productivity on lime,. t/day	200	208	202	205
Productivity on active lime, t/day	144	141	149	146
Specific reference fuel consumption	207	217.0	220.6	218.8

On the other hand, the increase of natural-top mixture charge at the periphery creates turbulence in the wall-near area and improves mixing conditions. Finally both factors have a positive effect on blast-furnace operation and promote increase in calcination degree (**Figure 2**). Besides, high-temperature zones are localized in the field of peripheral burners. Therefore top gas supply in them leads to softening of calcination and increase of active lime yield.

Thus, many-valued effect of top gas charge on blast-furnace operation leads to interesting result from the practical point of view: at furnace heating by natural-top mixture over the range of combustion heat 9.4-33.5 MJ/m^3 the basic parameters of blast-furnace operation (the structure of heat balance and calcination quality) almost do not vary.

This conclusion can be explained by that the shaft surface has no free space of working space as heat-treatment furnaces and boiler units have. In a dense layer the basic heat transfer from gases to material surface is carried out via convection. Therefore at rock gas substitution by low-calorie fuel there is no effect of sharp drop of radiant component of heat transfer.

The estimation of economic parameters of this power saving measure showed that at furnace heating by natural-top mixture with heat of combustion 9.4 MJ/m^3 the approximate hour saving of rock gas in absolute units is 322 m^3/h (**Figure 2**).

In the prices as of 2011 (at cost of natural and blast-furnace gases 2600 UAH and 50 UAH per 1000 m^3, respectively) hour saving of money resources will reach 703 UAH/h.

Conclusions

On the basis of results of investigation of top gas effect on blast-furnace operation it is determined that quality indices of lime are aggravated at top gas supply on the central burner and improved at supply on peripheral burners.

Joint supply of a top gas over the range of combustion heat of natural-top mixture 9.4-35 MJ/m^3 enables to save parameters of blast-furnace operation without changes. Thus the factor of rock gas substitution by top gas is close to one.

The offered regime of blast-furnace heating by natural-blast-furnace mixture ensures rock gas saving of 30 %, and annual fuel cost reduction is 7.04 million UAH in the prices as of 2011.

References

1. O.G. Feodorov. *Stal*, 1990, No. 2, pp. 102-105.*

2. Yu. P. Nekhlebaev. *Ekonomiya Topliva Pri Proizvodstve Izvesti*, Moscow, Metal-lurgiya, 1987, 136 p.*

3. V.V. Madison, V.T. Ryazanov, Ya.M. Gordon. Proceedings of International Conference “*Thermophysics and Informatics in Metallurgy: Achievements and Problems*”, Yekaterinburg, UGTU, 2000, pp. 136–142. *

4. S.I. Sazonov, S.N. Foris`, O.G. Fedorov. *Tyeoriya i Praktika Metallurgii*, 2005, No. 3, pp. 7–10. *

5. S. M. Foris`, S.S. Fedorov, M.V. Gubinskiy. *Regional`Nyy Mizhvuzivs`Kyy Zbirnik Naukovih Prats`*, Dnipropetrovsk, Sistemni tehnologii, 2008, Vol. 2, pp. 98–104. *

6. S.M. Foris`, S.S. Fedorov, O.G. Fedorov. Proceedings of International Conference “*Heat and Power Engineering in Metallurgy*”, NMetAU, Dnepropetrvsk, Ukraine, 7–9 October 2008, Dnepropetrovsk, Novaya Idyeologiya, 2008, pp. 252–253. *

* Published in Russian

Received April 04, 2011

Эффективность использования доменного газа в противоточных известково-обжиговых печах

Губинский М.В., Федоров С.С.,
Форись С.Н.,Агаджанян А.В.

В связи с высокой стоимостью первичных энергоресурсов актуальной является разработка альтернативных способов отопления печных агрегатов. Для шахтной известково-обжиговой печи суточной производительностью 200 т были проведены исследования показателей ее работы при частичной замене природного газа доменным. Изучено влияние доменного газа при подаче на боковые и периферийные горелки.