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Possibility Analysis of Pyrolysis Gas for Firing Pusher Furnace Heating

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Abstract : The article compares the possibilities of using natural gas, coke oven gas and gas from the pyrolysis of municipal solid waste RDF (refuse derived fuel) for pusher furnace heating at the department of the rolling mill of one of the national steel mills. Taking into account the high calorific value of the pyrolysis gas, an economic assessment of the above-mentioned venture was made, with particular emphasis on the benefits associated with its use in the metallurgical industry. The analysis takes into account the prices prevailing on the market in 2019.

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1 Introduction

The gaseous fuels used in the steel industry are natural gas, coke oven gas and blast furnace gas. The consumption of natural gas in the industrial sector is constantly growing, which is closely related to the decline in the demand for coal, resulting from increasingly restrictive European Union regulations regarding the improvement of air quality. Moreover, in order to ensure reliable supplies of natural gas, the transmission networks in our country are constantly developing. The greater use of natural gas compared to fuel oil or LPG is encouraged by the lower price, lack of need for tanks and, above all, residue-free combustion. On the other hand, coke oven gas is one of the process gases which, in its raw form, due to the presence of undesirable components such as tar, ammonia, benzene hydrocarbons or hydrogen sulphide, requires multi-stage treatment. As far as gas management is concerned, about 50 % of the total amount is used by coking plants for their own purposes, e.g. for firing coke oven batteries or generating process steam, while excess gas, due to the obligation to manage it, is sold outside. At present, a practical and economical solution is to use the surplus gas in the rolling mill department for firing heating furnaces. In addition to the demonstrated advantages of replacing natural gas with coke oven gas, there are also disadvantages. One of them is the increased risk of poisoning by carbon monoxide, which is a fuel component. On the other hand, the gaseous fuel obtained in the blast furnace process is blast furnace gas. The production volume of the aforementioned gas is 1,200 to 2,000 $m^3.t^{-1}$ of pig iron, and additionally, it has a calorific value in the range of 2.7-4.0 $MJ.m^{-3}$; therefore, after cleaning it from process dust and enriching it with coke oven or natural gas, blast furnace gas is often used as a gas fuel in the steel industry. Moreover, if modern burners or preheating of the combustion air are used in blast furnace blast heaters, this gas can also be used without enrichment. Pyrolysis gas is also noteworthy, which is a product of the pyrolysis of biomass, municipal waste or tires. The composition and calorific value of the said syngas depend on the physicochemical properties of the charge, as well as the process temperature. The calorific value of pyrolysis gas obtained from biomass ranges from 10-15 $MJ.m^{-3}$, from municipal waste about 15 $MJ.m^{-3}$, and in the case of tires even above 50 $MJ.m^{-3}$, thanks to which it can be used for the production of electricity and heat, superheated steam or other fuels. The aforementioned premises encourage the use of the said gas as fuel in the steel industry [1–7].

During the hot rolling process, it is important to heat the steel charge to the appropriate rolling temperature, i.e. between 1050 and 1300°C, as well as to ensure its even distribution. In domestic hot rolling mills, natural gas-fired pusher-type heating furnaces are most often used, and also, if possible, a mixture of coke oven gas and blast furnace gas or coke oven gas only. The advantage of the aforementioned furnaces is their high efficiency, low consumption of thermal energy, and the possibility of heating the charge to high temperatures. However, their main disadvantage is the impossibility of simultaneous heating of the charge with different cross-sections, resulting from the differences in the charge movement speeds [8,9].

2 Possibilities of using pyrolysis gas for firing metallurgical heating furnaces

This article provides an economic assessment of the use of pyrolysis gas for firing heating furnaces. The pusher-type furnace described in [10] was analysed. The device is fired with natural gas or coke oven gas and is divided into three zones:

- heating 1073 K – 1373 K,
- heating 1373 K – 1623 K,
- equalizing 1423 K – 1553 K.

The considered furnace is divided into six control zones and equipped with 105 control burners located on the ceiling and side walls [9,10].

Table 1 summarizes the calorific value and chemical composition of gaseous fuels used for firing the above-mentioned heating furnace versus pyrolysis gas.

Table 1 Calorific value and chemical compositions of selected gaseous fuels

	Units	Natural gas[11]	Coke oven gas[11]	Pyrolysis gas[12]
LHV	[MJ. m^{-3}]	34.43	17.5	22.8
CH_4	[%]	97.1	25	32.9
H_2	[%]	-	58	29.4
C_mH_n	[%]	1.7	3	7.2
N_2	[%]	1.1	4	-
CO_2	[%]	0.1	2.5	13.2
CO	[%]	-	7	11.3
O_2	[%]	-	0.5	-
Other	[%]	-	-	6
Price for 1000 m^3	[PLN]	1400**	410**	300*

* estimated gas price; ** prices valid in 2019

As can be seen from the above data, natural gas is characterized by a high content of methane (over 97 %) and trace amounts of hydrocarbons, nitrogen and carbon dioxide, as well as a high calorific value of 34.43 MJ.m^{-3}. On the other hand, coke oven gas is characterized by an almost twofold lower calorific value, a high hydrogen content of 58 %, and a significantly lower methane content (25 %). Its composition also includes carbon monoxide at the level of 7 % and traces of other components. Taking into account the syngas from the pyrolysis of RDF, it is possible to notice the almost 1/3 methane content in the fuel composition, a high content of hydrogen (29.4 %) and carbon monoxide (11.3 %), as well as the highest hydrocarbon content among the above-mentioned gases, at the level of 7.2 %. Additionally, the calorific value of the said gas is 5.3 MJ.m^{-3} higher than in the case of coke oven gas. On the other hand, pyrolysis gas produced from RDF in one of the national thermal waste conversion plants has a 11.2 MJ.m^{-3} higher calorific value than coke oven gas, which encourages its wider use as a gas fuel in the steel industry [11,12].

3 Economic aspect of using pyrolysis gas for energy purposes

Taking into account the high calorific value of the pyrolysis gas, an economic analysis was made of the use of the said gas for firing a pusher-type furnace, compared to the currently used fuels. Table 2 shows the consumption of the analysed gaseous fuels depending on the efficiency of the heating device.

Table 2 Consumption of selected gaseous fuels depending on efficiency of pusher furnace [10]

Furnace efficiency [t.h^{-1}]	20	40	60	80
Furnace power [MW]	10.41	18.22	26.03	33.84
Consumption of natural gas [m^3/h]	1047	1832	2618	3403
Consumption of coke oven gas[m^3/h]	2063	3609	5157	6704
Consumption of pyrolysis gas [m^3/h]	1581	2766	3953	5139

As can be seen from the above data, the consumption of the above-mentioned gaseous fuels was determined for the efficiency of a pusher-type furnace in the range of 20 to 80 t.h^{-1} and power in the range of 10.41 to 33.84 MW. To estimate the consumption of coke oven gas and pyrolysis gas instead of natural gas, the so-called conversion factor for the conversion of natural gas to coke oven or pyrolysis gas is described by Equation (1):

$$n = \frac{Wd_{gz}}{Wd_{gza}} \quad (1)$$

where:
Wd_{gz} - calorific value of natural gas MJ.m^{-3},
Wd_{gza} - calorific value of substitute gas MJ.m^{-3}.

The determined value of the above-mentioned the coefficient is 1.97 for coke oven gas and 1.51 for pyrolysis gas. By analysing the consumption of the above-mentioned of gases and their prices, the costs of 1 hour of operation of a pusher-type furnace were compared (Figure 1).

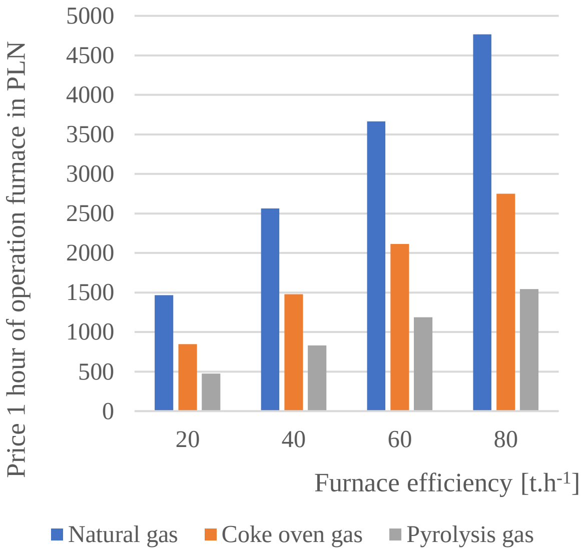
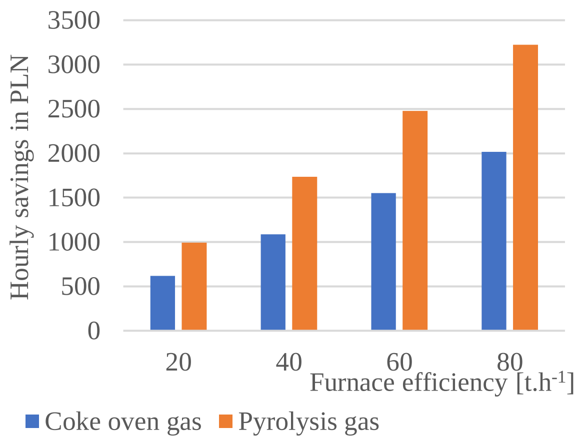


Figure 1 Comparison of price of 1 hour of furnace work for various gaseous fuels

Savings, both hourly and daily, resulting from the use of coke oven and pyrolysis gas instead of natural gas are presented in Figure 2.



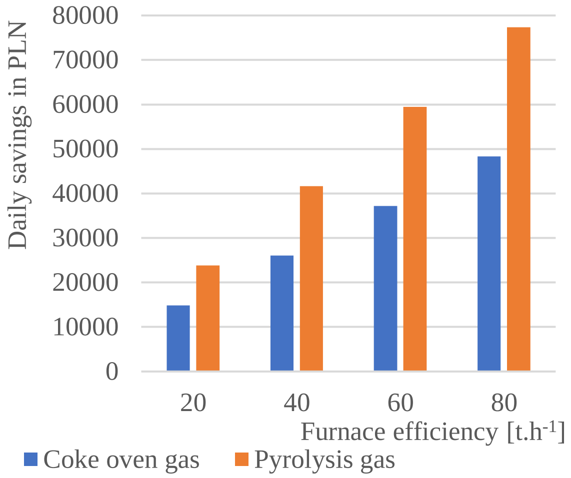


Figure 2 Economic effects of using coke oven gas and pyrolysis gas

With the above data in mind, there are significant benefits to using pyrolysis gas instead of natural gas. The greatest savings result from the use of syngas from the pyrolysis of RDF, from 992 PLN.h^{-1} with a furnace capacity of 20 t.h^{-1} to even 3222 PLN.h^{-1}, with a capacity of 80 t.h^{-1}. These savings are respectively 372 PLN.h^{-1} (with a capacity of 20 t.h^{-1}) and 1207 PLN.h^{-1} (with a capacity of 80 t.h^{-1}) higher than in the case of coke oven gas. Real savings for rolling mills in relation to 1 ton of heated slab, resulting from the replacement of natural gas with the above-mentioned gases are summarized in Figure 3.

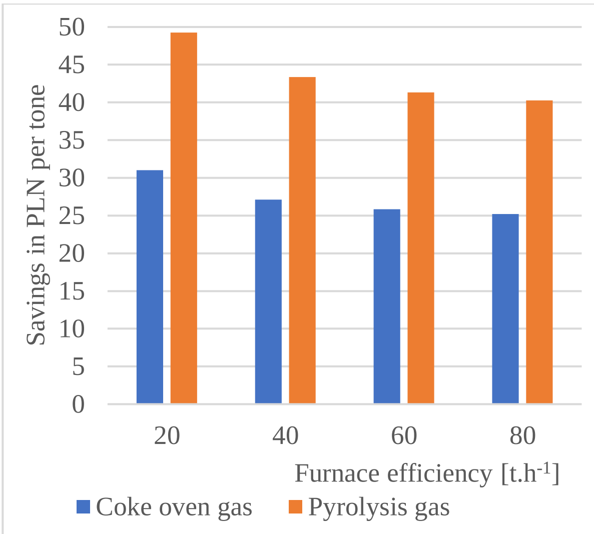


Figure 3 Savings for rolling mill in relation to heated slab

By analysing the above data, an increase in savings in relation to the heated charge was found in the range from 25.19 to 31.00 PLN.t^{-1} in the case of coke oven gas and 40.28 to 49.60 PLN.t^{-1} by using pyrolysis gas, along with a decrease in the efficiency of the pusher-type furnace.

4 Conclusions

In the face of the intensive optimization of production processes and reduction of incurred financial outlays, there is an opportunity to increase the competitiveness of the analysed rolling mill, thanks to the use of pyrolysis gas for firing a pusher-type furnace. With an annual steel production volume of 500,000 t, savings will amount to 20.140 million PLN; thus, it is possible to consider the construction of an RDF pyrolysis installation in the vicinity of the rolling mill. Nevertheless, it is necessary to take into account the costs of building a fuel supply pipeline, the costs of modernizing the gas-air installation of the furnace, including the modernization of the burners. At present, to supply a furnace with a capacity of 20 t.h^{-1}, approximately 12 modules must be installed in the pyrolysis installation, each of which produces approximately 130 m^3 of syngas per hour. Taking into account the capabilities of the above-mentioned installation, about 40 modules are needed to generate the amount of pyrolysis gas necessary to power a pusher furnace with a capacity of 80 t.h^{-1}. Currently, the installation is at the research and development stage; nonetheless, the high calorific value of the obtained syngas encourages its further improvement, as well as wider use of the said gas fuel. In addition, pyrolysis gas may contribute to a lower consumption of natural gas, which will allow diversification of the fuel and energy sources in our country, and will also bring tangible economic benefits.

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