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ECOLOGICAL AND ECONOMIC BENEFITS AND SAFETY OF THE USE OF COAL GAS IN INDUSTRY

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Abstract: Possibilities of use of degassing and carbon gas in industry. Degassing gas represents a waste during coal mining so far and this issue is not effectively solved in Ostrava region up till now Ecological aspects, safety, economic aspects. Coal deposits represent a special case in which the deposit is both a source of coal and reservoir of gas. For the thing is that, in the process of coalification of plant residue, coal bed gas came into being of which the main component is methane. Gas from mining degassing can be used as a substitute fuel for the blowing of blast furnaces. This would not only make it possible to reduce the specific consumption of coke, but also contribute to a better blast furnace. An economic effect is also negligible if we characterize degassing gas as waste gas.
Keywords: degassing gas, carbon gas**,** consumption of coke, blast furnace, economic benefits

1. INTRODUCTION

In the Czech Republic, a lot of attention was paid to the problems with securing carbon gas exploitation. Moravian Silesian region, Czech Republic is typical of coal mining and mining gas occurrence. The gas is during the coal mining drawn and further it is exploited as degasation gas.The methane release that accompanies the coal mining from the coal deposits is a risk factor, because this mixture is explosive at the concentration of 5 to 15 % of methane mixed with air. (Roubíček et al., 2007) In the Moravian-Silesian Region, local gas sources are used in parallel with the natural gas of “petroleum origin”; for instance, these involve coke-oven gas and carboniferous gas from surface and mine degassing systems, the so-called “gas from degassing systems”. The utilisation of these gases is locally restricted to the neighbourhood of their origin as well as to the utilisation for the industrial (or agricultural, as the case may be) consumption only. Gas, the origin of which is connected with significant coal deposits in the Moravian-Silesian Region, belongs to the domestic sources of natural gas in the Czech Republic. Methane, as a product of the coalification process is physically bound in the coal mass or present - as free gas - in pores and cracks in coal as well as neighbouring rocks. In order to eliminate explosion hazards of methane gas released during coal-mining processes, it was necessary for the deep mining in the Ostrava District to create ventilation and withdrawal systems for the dangerous gas – i.e. the so-called mine degassing systems. At the surface near each colliery, the so-called “degassing stations” were constructed and equipped with vacuum pumps sucking the gas from degassing boreholes and some abandoned mines (called as the “old workings”). During the gas withdrawal, its partial dilution takes place by sucking-in of the mine atmosphere. The technical data of the degassing gas are listed in Table 1. (Pustějovská et. al., 2013)

Table 1
Technical data of the degassing gas (Pustějovská, Brožová, and Jursová 2013)

Technical data	**quantity/volume**
Gas overpressure operating	Operating 7-12 kPa Max. 55KPa
Current consumption for enrichment	5000 – 9500 $m^3.h^{-1}$
Temperature	+5 až +30 °C
Heat capacity	18.2 – 20.5 MJ $.m^3$
Specific gravity	0.97 – 1.02 kg . m^3
Average composition	CO_2 2.4 – 4.3 % O_2 2.6 – 4.5 % N_2 35.8 – 41.7 % CH_4 51.4 - 57.8 %

Source: (Pustějovská, P. et al., 2013)

As another source of the gas there is the possibility of extraction of the so-called “sorbed gas” (carbon gas). This is methane gas bound in the porous structure of the coal matter itself. Therefore the attention is also drawn to the possibility of using so called carbon gas, currently it is preliminarily thought of mining at Frenštát mine.

2. METHODOLOGY OF RESEARCH

Methods of the evaluation of application of waste mine gas (degassing gas, carbon gas) during iron pig production results from general elementary relations of determination of costs on blast-furnace process and from simulation results and practical tests when gaseous alternative fuel is added. (Konstanciak et al., 2002) (Jursová et al., 2017) The eco-innovation in connection with metallurgical products means technical, organizational and marketing changes. (Gajdzik et al., 2011) The conventional route for making steel consists of sintering or pelletization plants, coke ovens, blast furnaces, and basic oxygen furnaces (Legemza et al., 2010; Pribulova et al., 2010; Jonšta et al., 2016).

Coal gas injection has now become the most developed way to replace coke. Natural gas injection is used in the North American blast furnaces. The injection rates are in the range 40 to 110 kg. t^{-1} hot metal. Due to the high endothermic effect is required in order to maintain a suitable flame temperature at the tuyere.

The potential of further decrease of CO_2 emission of the traditional route is quite limited, probably no more than 5-10%. Indeed, blast furnace technology has reached such a high level of efficiency than any improvement is quite difficult. The research of carbon dioxide free technologies is initiated in many other sectors. (Václavík et al., 2016) The substitution of coke by injected coal gas has only little effect on the total CO_2 emission by injected carbon gas, degassing gas is effect major. (Bilík et al. 2002)
At present, the coal methane gas is delivered to and used in metallurgical works in the form of additional gas blended to form a mixture with natural gas for burner systems (boiler rooms, preheating furnaces, etc.).
Gas from mining -degassing gas-can be used as a substitute fuel for the blowing of blast furnaces. In considered implementations of its potential use as a partial replacement for coke in blast furnaces, this would have to be managed by increasing of the gas pressure blown-in to the blast tuyeres by compressors. (Nogami et al., 2012) The current pressure of the delivered coal methane gas is only about 50 kPa.
Carbon gas contains 90 to 97% of methane (Tab.2) If injected, into the blast tuyeres, quite a number of chemical reactions take place, the summary of which results in an equation with its exothermic effect of 149,500 $kJ.kmol^{-1}$ CH_4.
In this way, incomplete combustion of methane takes place resulting in the origin of reduction gases, by which the gas is enriched with hydrogen, which in turn participates in an indirect reduction process. (Bernasowski, 2014) In a comparison with the carbon combustion in blast furnaces with the yield of 117,500 $kJ.kmol^{-1}$ C, it is evident that during the combustion of methane carbon (1 kmol) the same amount of heat is obtained, but the resulting volume of 67.2 m^3 is created, which – as compared to - 22.4 m^3 of CO resulting in the combustion of 1 kmol carbon of the coke origin represents resulting gas volume is 1.7 times larger.
Consideration of the usefulness of the use of degassing gas (or carbon gas) as a replacement fuel in blast furnaces is an important point of substitute coefficient, which indicates how much coke to replace 1 m^3 of degassing gas.
In order to demonstrate the results of calculations of the various alternatives for injection of gaseous substitute fuels under current batch and technological conditions, a calculation using average data from blast furnaces from the Czech Republic. (Bilík et al. 2002) (Jursová et al., 2016)
A model calculation of variants of gaseous fuel injection under current technological conditions was carried out. The typical composition of gases produced within the region is shown in the table 2.

Table 2
Composition of carbon gas and degassing gas

Gas	CH_4	N_2	O_2	CO_2
Degassing gas	54,6	38,8	3,5	3,1
Carbon gas	94.2	5.3	0.4	0.1

The results of prediction calculations for selected gases (degassing gas, carbon gas) are given in table 3 and 4.

Table 3
Coefficient of substitute (degassing gas) – prediction

Amount of degassing gas	kg.t^{-1} h.m.	0	40	60	80	100	120	140
Consumption of coke (min.)	kg.t^{-1} h.m.	462.5	445.4	437	328.7	420.4	412.1	403.9
Substitute coefficient	-	-	1.013	1.000	0.991	0.983	0.976	0.971

Table 4
Coefficient of substitute (carbon gas) – prediction

Amount of carbon gas	kg.t^{-1} h.m.	0	40	60	80	100	120	140
Consumption of coke (min.)	kg.t^{-1} h.m.	462	422	402	383	364	451	326
Substitute coefficient	-	-	1.013	1.000	0.991	0.983	0.976	0.971

3. RESULTS

The results of predictive calculations for selected gases are shown in the Figure 1 and 2. Decrease in specific coke consumption with injected amount of degassing gas is shown in the Figure 1.

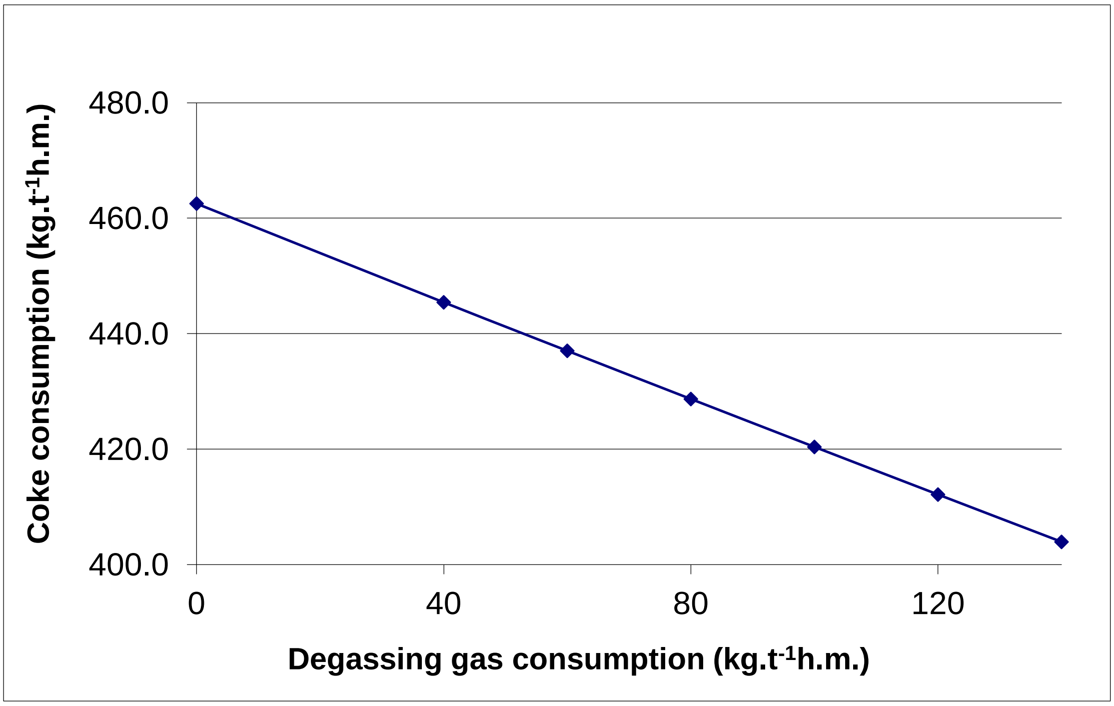

Fig. 1. Decrease in specific coke consumption with injected amount of degassing gas

Decrease in specific coke consumption with injected amount of carbon gas is shown in the figure 2.

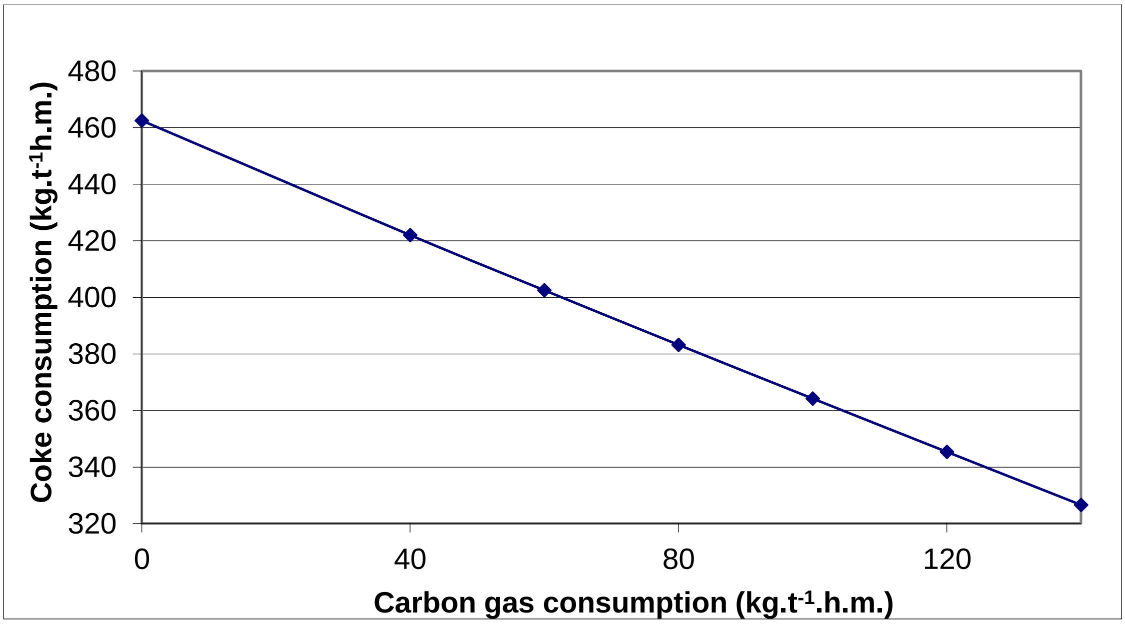

Fig. 2. Decrease in specific coke consumption with injected amount of carbon gas

4. DISCUSSION

Solution options of the use of coal gas for industry in the Czech Republic: the first option of provision of reducing gas from the mine degassing (methane content ranges 50-72 %). The second option of provision of reducing gas from the grass degassing (methane content ranging 70-90 %). The third option of provision of carbon gas (methane content ranges 95-99 %).

The results of these model calculations are in good accordance with the foreign knowledge about the consequences of degassing gas and carbon gas injection into the blast furnace tuyeres (Frőhling et al., 2003) (Babich and Gudenau, 2002).

However, the coal methane gas is not only a source of energy. Its uncontrolled leaks to the surface present a danger for the safety of people and their property, while the gas itself represents a significant air pollutant. Therefore, its extraction brings about a solution for these problems **.**

5. CONCLUSION

A screened charge (in pieces) and the use of high gas pressures are suitable for the degassing gas injections into blast furnaces. The favourable effect is brought by the use of oxygen-enriched air blast, because the total gas quantity is decreased in this case and, in addition, the use of oxygen helps to equalise furnace hearth temperatures. Concurrent blowing of natural gas and oxygen equalises the heat distribution along the blast furnace height and it thus contributes to the furnace production capacity. A decrease in the sulphur content in the furnace represents an additional benefit.

The gas recovery from mines before their abandonment and systematic search for potential sources of methane in remaining active mines stabilises the current production mine gas from degassing systems in both quality and quantity. If the gas is sucked off only from the abandoned mines, the final product is of a higher quality, with the methane content about 70% or even more.

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REFERENCES

Babich, A. I., Gudenau, H.W. 2002. *Choice of technological regimes of a blast furnace operation with injection of hot reducing gases.* Rev. Metal.,38, 288-305.

Baricova, D., Pribulova, A., Rosova, A. 2013. *Steelmaking Slag - Waste or Valuable Secondary Raw Material.* Geoconference on Energy and Clean Technologies, Sofia, 437-442.

Bernasowski, M., 2014. *Theoretical Study of the Hydrogen Influence on Iron Oxides Reduction at the Blast Furnace Process*. Steel Research International, 85, 670-678.

Bilík, J., Roubíček, V., Vilamová, S., Pustějovská, P. 2002. *Actual Possibilities of Coal Utilization in Iron Metalurgy*. Metalurgija, 42, 107-111.

Frőhling, C., Babich, A., Gudenau, H. W., Senk, D. 2003. *Aktuelle untersuchungen zum Einblasen in den Hochofen.* 18. Aachener Stahlkolloquium. Aachen, 2, 43-56.

Gajdzik,B., Burchard-Korol, D. 2011. *Eco-innovation in manufacturing plants illustrated with an example of Steel products development*. Metalurgija, 50, 63-66.

Jonšta P., Váňová P., Brožová S., Pustějovská P., Sojka J., Jonšta Z., Ingaldi M. *Hydrogen embrittlement of welded joint made of supermartensitic stainless steel in environment containing sulfane*. Archives of Metallurgy and Materials, 2016, vo. 61, Nr 2A, s. 709-712.

Jursova, S., Pustejovska, P., Bilik, J., Honus, S. 2017. *Evaluation of Reducibility of High and Low Basic Sinter in Economical Point of View.* 26th International Conference on Metallurgy and Materials, Ostrava, Tanger, 2176-2181.

Jursova, S., Pustejovska, P., Brožová, S. Bilik, J. 2016. *Mathematical simulation of blast furnace operation.* Ironmaking and Steelmaking Processes: Greenhouse Emissions, Control, and Reduction, 139-150.

Konstanciak, A., Brozova, S., Pustějovská, P. 2013. *The use of alternative energy source in Poland and Europe.* Rynek energii, 107, 33-36.

Legemza, J., Frőhlichova, M., Findorak, R., Bakaj, F. 2010. *Emissions CO and CO_2 in the Sintering Process.* 10th International Multidisciplinary Scientific Geoconference, Albena, 567–572.

Nogami, H., Kashiwaya, Y., Yamada, D. 2012. *Simulation of Blast Furnace Operation with Intensive Hydrogen Injection*. ISIJ International, 52, 1523–1527.

Pustějovská, P., Brožová, S. and Jursová, S. 2013 *Blast furnaces intensification by gases and oxygen*. Wybrane zagadnienia energo-fizyczne w produkcji stali, 36, Czestochowa, 22-35.

Roubíček, V., Pustějovská, P., Bilík, J., Janík, I. 2007. *Decreasing CO_2 Emissions in Metallurgy*. Metalurgija, 46, 53–59.

Urban, P. 2010. *Utilization of gas from closed underground coal mines*. GeoScience Engineering, 2, 27-35.

Václavík, V., T. Dvorský, V. Šimíček, M. Ondová, J. Valíček, M. Kušnerová, Gola, L. 2016. *Steel Slag as a Substitute for Natural Aggregate in the Production of Concrete*. Solid State Phenomena, 244, 77-87.