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APPLICATION OF LOW CARBON TECHNOLOGY IN METALLURGY

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Abstract: The paper deals with possibilities of low carbon technology application in metallurgy. It sums up the world wide experience with them and presents possibilities of their application in metallurgical production in view of carbon dioxide emission responsible for greenhouse effect and global warming of the Earth. It summarizes research projects in this field and presents the results and conclusion resulting from them. It is aimed at the possibilities of low carbon application in sinter and subsequently in blast furnace process. It presents research on reducibility of metallurgical ekosinter produced with share of biomass in comparison with sample of industrial one. It describes the testing methodology carried out in accordance with ISO 4695:2007. The samples were tested in reduction atmosphere created by 40% CO_2 and 60% N_2 simulating conditions in blast furnace aggregate at temperature 950°C. The obtained results confirmed better reducibility rate of ekosinter which reached the reduction index (dR/dt) 1.15, in comparison with industrial sinter of reduction index 0.83.
Keywords: carbon dioxide emission, biomass, sinter, metallurgy

1. INTRODUCTION

Low-carbon technologies are one of key innovative trends through all the industrial sectors. In the countries of European Union (EU), a significant decline in carbon dioxide emissions has been recorded since 1990. However, carbon dioxide emissions in the modern society still present an alert. According to Eurostate database, in 2016 2,876,650,029 tonne of carbon dioxide was produced in all EU countries. The biggest producer is Germany with emission higher than 670 mil tonne followed in 2016 by United Kingdom with half emission (310 mil tonne) then Poland (275 mil tonne), Italy (271 mil tonne) and Spain (211 mil tonne). The decline in emission is recorded in all the mentioned countries. (Konstanciak, 2017) From the emission per capita interesting findings have resulted (Fig. 1). The most significant decline in carbon dioxide emission per capita in last ten years was recorded in Slovakia given by dynamic application of advanced technologies into current production.

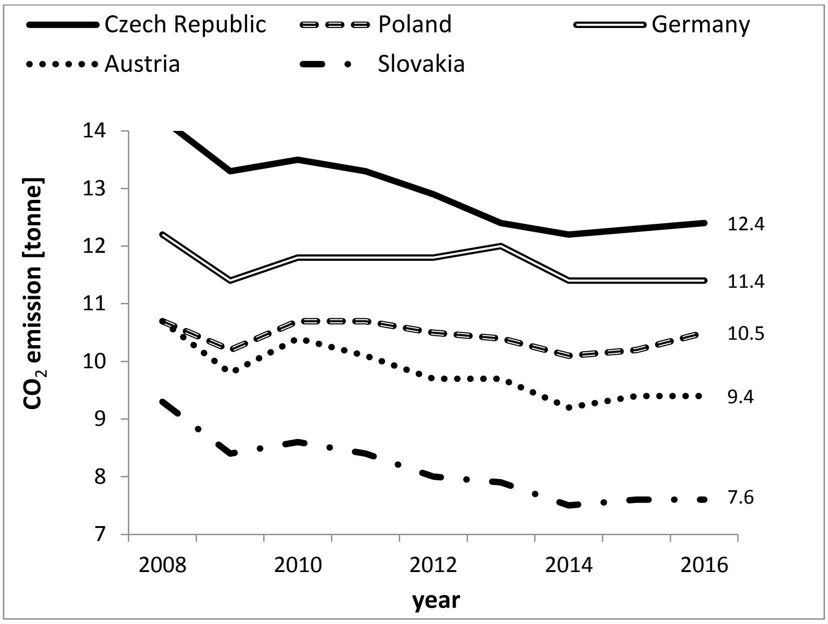

Fig. 1. Carbon dioxide emissions per capita in chosen countries of central Europe (based on data from Eurostat database)

Germany as the biggest producer of carbon dioxide is in view of emission per capita overcome by the Czech Republic, a country populated over 10 mil people and covering an area of 78,866 square kilometers. (‘Database - Eurostat’ n.d.), (Burchart-Korol et al., 2018) It is given by its export-oriented market economy based in manufacturing. The strong position in its national economy has a processing industry.

Metallurgy and metal production has a long-lasting tradition. Ironmaking and steelmaking is one of the most energy-intensive industries in the world. Still coal based metallurgical production is dependent on fossil fuels; it is an industry emitting the biggest carbon dioxide emission world widely. Globally, iron and steel production accounts for about 6 % of anthropogenic carbon dioxide emissions each year (Onarheim, Mathisen and Arasto, 2015).

Over the last decade a number of researchers and development activities all over the world have been investigated for low-carbon and sustainable iron and steel production. The most extensive research program is the Ultra-low CO_2 Steelmaking (ULCOS). It is a consortium of 48 European companies and organization from 15 European countries and supported by European Commision. It is divided into two phases ULCOS I in 2004 and ULCOS II in 2010 with projection up to year 2050. The main aim of this massive project is to reduce CO_2 emission by at least 50%. It includes several research projects on low carbon technologies listed in Table 1 (Abdul Quader et al., 2016).

Beside the international large-scale projects, there are many research initiatives aimed at decrease in carbon dioxide emissions in all the production phase of metallurgical operation. Many literature sources refer to this topic. The environmental sustainability of metallurgical production is studied by (Kardas, 2016; Ingaldi and Dziuba, 2016). Possibilities of carbon dioxide emissions reduction in sintering plants are studied in (Mousa et al. 2016; Legemza et al. 2010). In terms of energy consumption and CO emission (Baricova, Pribulova and Rosova, 2013) evaluates steelmaking process. The research of carbon dioxide free technologies is initiated in many other sectors (Václavík et al., 2016; Dvorsky et al., 2015; Regucki et al., 2017).

Table 1
Summary of technologies (Abdul Quader et al., 2016)

Technology	Main advantages compared to reference	Potential drawbacks compared to reference
ULCOS-BF (Top gas recycling) with CCS	50% CO_2 reduction compared to average blast furnace (BF)	Higher operational costs
HIsarna (Coke free steelmaking) with CCS	80% CO_2 reduction compared to average BF with CCS. 20% without CCS. Lower investments and operational costs due to broader range of available inputs	Needs replacement of existing blast furnaces
ULCORED (Fastmelt process of direct reduction) with CCS	55% CO_2 reduction compared to average BF with CCS, 5% without CCS. Lower operational costs due to broader range of available inputs.	Essential replacement of existing BF. Higher investments costs.
Electrolysis (ULCOWIN &ULCOLYSIS)	Probably no carbon is needed in the production process	
Hydrogen Reduction		
Use of Sustainable Biomass		

Source: (Abdul Quader et al., 2016)

The aim of the paper is contribute to the topic of low carbon technologies and within the mentioned innovative technologies present laboratory results of use of sustainable biomass in metallurgical sinter production processed in blast furnace operation. This technology is not widely industrially developed. Using biomass as a bioreducer in the blast furnace could be one of the process to reduce the fossil CO_2 emissions of metallurgy. This paper, hopefully will be useful for this project application and in future perspective might contribute to low carbon technologies and low carbon dioxide emissions responsible for global warming of the Earth.

2. METHODOLOGY of RESEARCH

For the testing of biomass potential to be a bioreducer two batches of samples were chosen. There were tested two kinds of metallurgical sinter of similar composition and FeO content (Tab. 1). One batch of sinter originated from a metallurgical company was used. It was compared to the second batch of laboratory sinter with share of biomass. This ekosinter was prepared in laboratories of Technical University of Kosice at Department of Metallurgy, Materials and Recycling (Froehlichova et al., 2014). The research team at Centre ENET, VSB – Technical University of Ostrava carried out tests of reducibility of both these batches. Tests of sinters reducibility dR/dt (%/min) were conducted according to ISO 4695:2007. The samples of size range 10.0 mm – 12.5 mm were oven-dried to constant mass at 105 °C ± 5 °C and before preparation of the test portions they were cooled to the room temperature. The test portion of 500 g was isothermally reduced at 950 °C in a fixed bed of reduction tube with a removable perforated plate inside to ensure a uniform gas flow using reducing gas consisting 40.0 % of CO and 60.0 % of N_2.The portion was weighed at specified time intervals until its degree of reduction reached 65 %.(Jursova et al. 2017) The degree of reduction Rt [-], relative to the iron (III) state after t min is calculated, as follows (1) ('ISO 4695: Iron Ores for Blast Furnace Feedstocks - Determination of the Reducibility by the Rate of Reduction Index' 2007).

$$R_t = \frac{0.111w_1}{0.430w_2} + \frac{m_1 - m_2}{m_0 \cdot 0430 \cdot w_2} \cdot 100 \quad (1)$$

Explanation of marks: m_0 - start mass of the test portion before heating to reduction temperature 950 °C [g], m_1 - mass of the portion heated for 950°C and immediately before starting the reduction [g], m_t - mass of the test portion after reduction time t [g], w_1 - iron (II) oxide content [%], w_2 - total iron content [%]
The reducibility index dR/dt [-], expressed as the rate of reduction at the atomic ratio of O/Fe of 0.9 [%/min] is calculated from equation (2) and presented in Table 2.

$$\frac{dR}{dt} = \left(\frac{O}{Fe} = 0.9\right) = \frac{33.6}{t_{60} - t_{30}} \quad (2)$$

Explanation: t_{30} - time to attain a degree of reduction of 30% [min], t_{60} - time to attain a degree of reduction of 60 % [min]

3. RESULTS

The results of tested samples confirmed a good effect of biomass on material reduction. Table 1 presents results of sinter analysis. The analysis of properties important for evaluation of reducibility working as input data was determined.

Table 1
Properties of tested sinter

Batch	FeO [%]	Fe [%]	Basicity
Industrial sinter	8.35	53	1.22
Ekosinter	8.36	50	1.18

Table 2
Results of sinter reducibility testing

Batch	dR/dt
Industrial sinter	0.81
Ekosinter	1.15

The ekosinter produced with biomass share was evaluated as a more porous sinter of dark color and less strength in disintegration test, on the other hand. Biomass constitutes mainly carbon, hydrogen, oxygen, nitrogen, and sulfur. The carbon content in the wood biomass is low compared to fossil fuels for example coal, coke or oil used in ironmaking and steelmaking (Nogami, Yagi and Sampaio, 2004). Besides, the sulfur content is also low approximately 0.01-1 wt% which is advantageous for blast furnace ironmaking (Abdul Quader et al., 2016) The industrial sinter used in test was evaluated as a sample with lower reducibility than it was expected. Regarding its high basicity, better value has been assumed. The result has been affected also by its low porosity which slows down the flowing of reduction gas from the sample surface to its mass. There were also calculated kinetic constants for both samples which describe the reduction process and its rate of oxide reduction from hematite to magnetite (k_1) to wüstite (k_2) and finally to iron (k_3). Obviously, more favorable reduction rate of ekosinter was confirmed.

Table 3
Kinetic constants of oxides reduction rate

Sample	k1[-]	k2[-]	k3[-]
Industrial sinter	0.00774	0.00419	0.00046
Ekosinter	0.00236	0.00034	0.00035

4. DISCUSSION

Also, worldwide studies on production of sinter with biomass share confirm good results with its application into sintering process. The higher volatile content and better reactivity of biomass positively affect the combustion rate of biomass (Wei et al., 2017). Kawaguchi et al. in (Kawaguchi and Hara, 2013) reported that the sinter produced by using biomass as the fuel, although at a yield and tumbler strength slightly lower than those from sintering using coke or coal, could meet the requirements of ironmaking in blast furnace. One of the most remarkable advantages of using biomass is its potential in reduction of CO_2 emission. Wei et al. referred in (Wei et al., 2017) that the net CO_2 emission from the charcoal system used in metallurgical technologies is only about 50kg-C/t than in the conventional system with CO_2 emission about 528 kg-C/t. Jha et al. in (Jha and Soren, 2017) explain that biomass is a carbon neutral source of energy where the CO_2 generated from the industrial operations like sintering has been absorbed again by the biomass and again utilized as fuel.

5. CONCLUSION

Biomass is clean and renewable energy which has a potential to partially substitute fossil energy. Because of fossil resources depletion, research on biomass application, mainly as fuels and reducing agents, into metallurgical processes has received growing interest. The carried out laboratory test confirmed good reducibility of ekosinter with share of biomass reaching dR/dt 1.15.

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