FEASIBILITY STUDY OF A WOOD SYNGAS CO-FIRING IN ANNULAR SHAFT KILN FOR LIME BURNING

Andrej SENEGAČNIK

ABSTRACT

The article deals with the wood syngas as a partial supplementary fuel for lime burning in the annular shaft kiln. Natural gas is a primary fuel. Wood chips are gasified with approved technology in the counter current gasificator. As an oxidizer the mixture of air with recycled flue gas with ~10 % oxygen is used. The moisture content in the wood chips dictates the amount and calorific value of syngas. The simulation of syngas and natural gas co-combustion in the lower combustion chambers shows that can be 20 % to 50 % of natural gas supplemented with the wood syngas.

POVZETEK

Članek obravnava možnost souporabe lesnega plina pri kurjavi na zemeljski plin v obročni jaškasti peči za žganje apna. Za uplinjevanje lesnih sekancev je predvidena preizkušena tehnologija protitočnega uplinjevalnika, ki kot oksidacijsko sredstvo uporablja mešanico zraka in recirkuliranih dimnih plinov z ~10 % vsebnostjo kisika. Količina in kurilnost nastalega lesnega plina je odvisna od vlažnosti lesnih sekancev. Simulacija sosežiga zemeljskega in lesnega plina v spodnjih gorilnikih peči pokaže, da je z lesnim plinom možno nadomestiti od 20 % do 50 % zemeljskega plina.

1. INTRODUCTION

Lime burning is several thousand years known procedure. The usage of lime in the living space doesn't have any negative impacts, therefore the production of lime is still increasing. Lime is used in many areas not just in civil engineering. Quick lime was also used as first chemical defense weapon in middle age when besieging [**Error! Reference source not found.**]. Technology of lime burning had been improving specially after the 2nd world war and a huge energy consumption decrease was achieved [**Error! Reference source not found.**, **Error! Reference source not found.**]. The world energy needs for construction material industry are enormous, specially the high temperature heat, also in Slovenia. The industrial branch of construction material and other minerals production is by the energy consumption on the second place, after the metal production. It represents 17 % Slovenian industry's energy [**Error! Reference source not found.**]. Primary fuel for lime burning was wood, nowadays all kinds of fossil fuels are used.

Being aware of negative impacts on fossil fuel usage – green gas effect, CO_2 tickets (the government calculates CO_2 emission from lime burning process, as a combination of CO_2 from fuel and CO_2 from limestone) manufactures are looking for alternative (cheaper) fuels, also renewable. The interesting thing is, that the lime can be also produced just by solar energy – by solar furnaces [**Error! Reference source not found.**].Some of the producers reduce fuel costs by co-burning some of the waste materials, which they get paid for their destruction. In Italy for example some lime producers use wood and wood waste as a primary fuel. Wood is dried and pulverized into wood dust particles, smaller than 0,3 mm. Wood dust is then injected into the combustion chambers as common fossil fuel. The pulverizing procedure consumes a lot of power for grinding and pulverizing the wood and also a large money investment into equipment. The long term investments are potentially unsafe due to small Slovenian economy system and still lasting global economy crisis. In this paper we therefore analyze a cheaper variant of wood consumption – wood gasification and wood syngas co-firing. Up to 50 % of natural gas can be replaced with syngas co-firing. The syngas calorific value and the replacement share are connected with the moisture of wood.

2. ANNULAR SHAFT KILN

The main features of the annular shaft kiln are the adjustability of the product quality from soft burnt to medium burnt and the continuous stream of exhaust gas with a high CO_2 content. Kiln was invented in Germany in the 1960's. Limestone is fed on the top. Then it is slowly moving down through preheating zone, which is followed by burning zone, first counter current zone, than co current zone and final cooling zone. The operating principle and energy flows analysis are well presented in literature [**Error! Reference source not found.**]. Specific heat consumptions are around 3800–4100 kJ per lime kg and 21–24 kWh power per lime tone. Capacity of kilns is 100–600 t of quick lime per day. Fig. 1 shows the kiln's cross section.

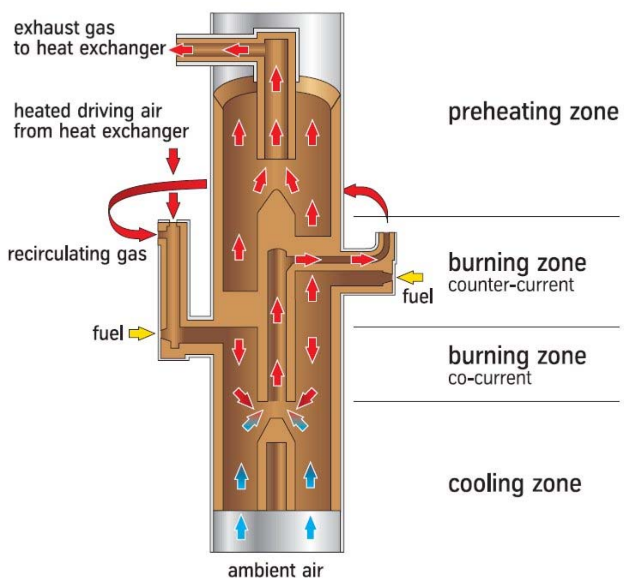

Figure 1: Annular shaft kiln for lime burning

3. COUNTER CURRENT GASIFIER

Well known technology is used for wood chips gasification. Wood gasifier is taken from the CHP (combined heat and power) plant with Stirling engine. The technology was developed in Denmark [**Error! Reference source not found.**]. Gasifier is counter current and therefore quite insensitive on the moisture in the wood chips. The out coming syngas temperature is 70 °C. Because of the high tar level syngas it is not appropriate for driving piston engines but it can be burned in the annular shaft kiln.

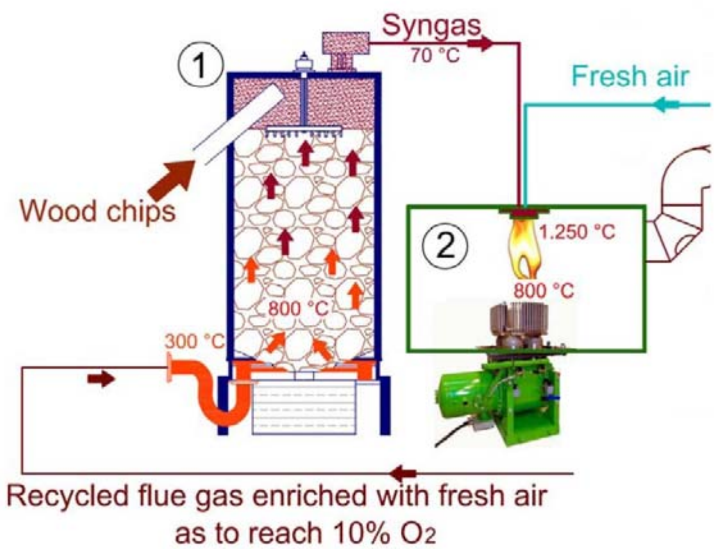

Figure 2: Counter current gasifier and Stirling engine, 1-gasifier, 2-combustion chamber of Stirling engine [**Error! Reference source not found.**]

One of the gasifier's characteristic is that air – flue gas mixture with ~10 % oxygen is used as an oxidizer. The benefits of such oxidizer are:

- easier regulation of gasification process
- due to high temperature flue gas recirculation higher efficiency is established
- possible usage of fresh (high moisture) wood chips

At annular shaft kiln there is also some hot flue gas (exhaust from driving air recuperator) and hot cooling air, which is otherwise wasted, available for mixing to get proper oxidizer for gasifier. The temperature should be around 300 °C with ~10 % oxygen.

In the Tab. 1 and 2 wood chips and syngas composition is presented. Values are given for three different moisture contents; absolute dry wood (special drying at 105 °C is required) with 0 % moisture, air dried wood chips with 12.5 % moisture and fresh wood chips with

47.4 % moisture. In the Tab. 2 the mass of syngas is expressed in kg of syngas per kg of wood chips. The theoretical combustion temperature is calculated for an air ratio 1.05 and the reactant temperature 20 °C. It is also evident from Tab. 2 that less syngas with lower calorific value is produced from fresh wood chips.

Table 1: Wood chips composition

		abs. dry wood	dry wood	fresh wood
carbon	mass. %	50	43,5	26,2
hydrogen	mass. %	6	5,2	3,1
oxygen	mass. %	44	37,9	22,8
water	mass. %	0	12,5	47,4

Table 2: Syngas composition versus moisture content in the wood chips [**Error! Reference source not found.**]

		abs. dry wood	dry wood	fresh wood
CO	mass. %	19,4	18,5	14,1
H2	mass. %	0,28	0,26	0,2
CH4	mass. %	2,8	2,7	2
CO2	mass. %	24,3	23,3	17,7
N2	mass. %	53,3	50,9	38,8
H20	mass. %	0	4,3	27,1
syngas mass	kg/kg	3,3	3,0	2,2
cal. value, lower	MJ/kg	3,7	3,5	2,7
theor. comb. temp.	°C	1454	1404	1132

4. USE OF THE SYNGAS IN THE KILN

Fig. 3 represents the heat and mass flow balance in the lower combustion chambers. Process was simulated with the software package IPSE-Pro 4.0 [**Error! Reference source not found.**]. Results on Fig. 3 are given for kiln's load 150 t per day. The share of natural gas was 100 %.

In process simulation we observe kiln parameters by increasing the share of syngas. The basic guidance in simulation was that the main process parameters; flue gas mass flow and temperature in the lower combustion chamber should stay constant. To keep these two parameters in the appropriate limits we can adjust just one parameter, mass flow of the secondary combustion air. Other two air flows – driving air and the cooling air can not be changed. The upper limit of syngas share is achieved when the amount of secondary air is reduced to just 10 % of its normal mass flow. This small amount of secondary air is needed for burner cooling.

Simulation results by syngas co-firing are given in Tab. 3. Syngas from air dried wood chips can replace up to 50 % of natural gas. If the syngas from fresh wood chips are used replacement share decreases to 20–30 %. By syngas co-firing some other parameters are also affected a bit, for example the flue gas composition. The influence of such minor parameter deviations to the quick lime quality can be established just experimentally with the real syngas co-firing in the kiln.

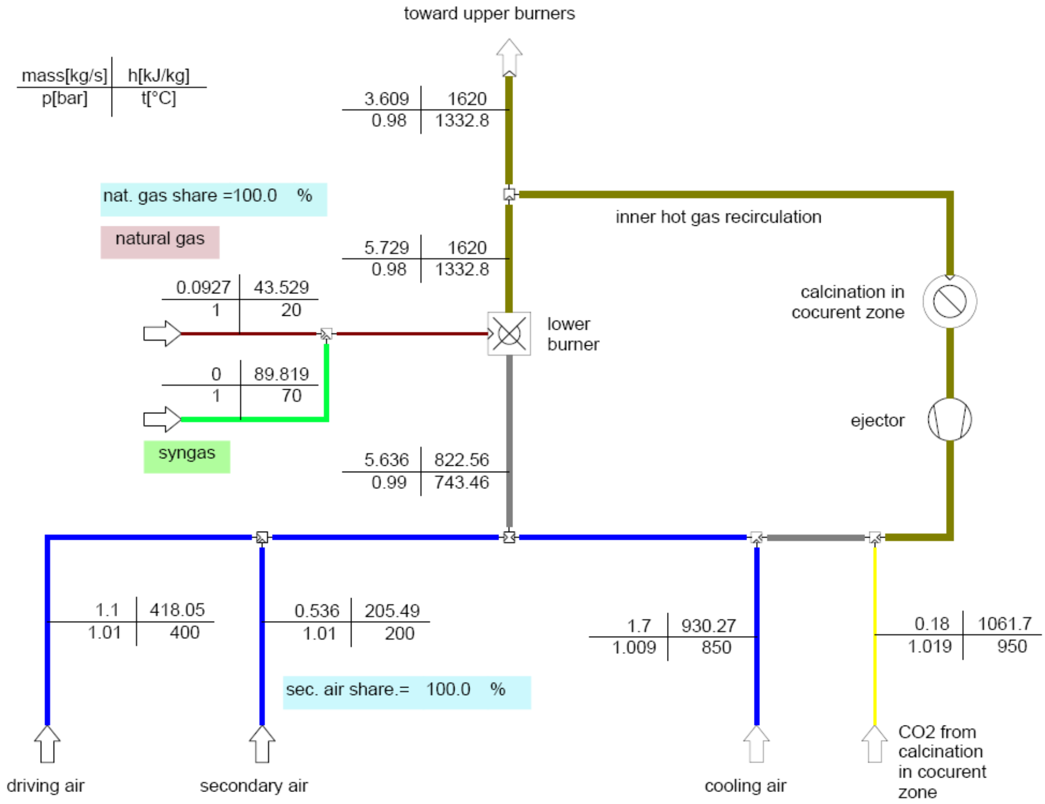

Figure 3: Model of lower combustion chambers

Table 3: Kiln parameters by syngas co-firing

fuel		natural gas	absolute dry wood		dry wood		fresh wood	
natural gas share	%	100	60	50	80	60	80	70
flue gas mass flow	kg/s	3,61	3,69	3,77	3,614	3,636	3,624	3,715
flue gas vol. flow	m3/s	17,19	17,15	17,4	17,05	16,92	17,25	17,51
combustion temperature	°C	1333	1339	1334	1335	1332	1326	1307
air ratio	-	2,69	2,37	2,31	2,51	2,37	2,31	2,21
sec. air share	%	100	18,7	9,3	52,2	9,3	28	9,3
syngas mass flow	kg/s	0,0	0,6	0,7	0,28	0,55	0,42	0,62

CO2 content	mass. %	12	18,3	19,7	15,2	18,2	15,8	17,2
O2 content	mass. %	10,9	8,4	7,9	9,5	8,3	8,4	7,6
combustion heat power	kW	4640	4807	4895	4697	4722	4837	4910
wood consumption	kg/h	0	595	757	338	663	682	1007

5. CONCLUSION

The paper treats use of wood biomass in lime burning industry to reduce fuel cost and CO_2 footprint. As a by-fuel the wood syngas was used in annular shaft kiln primarily fueled with natural gas. Wood syngas is produced separately in counter current gasifier and is injected into the lower combustion chambers. Wood chips with 15 % to 47 % moisture content are used as a biomass. Co-firing simulation predicts that 20 % to 50 % of natural gas can be replaced by wood syngas. The main lime burning process parameters are retained constant during simulation, i.e. flue gas mass flow and temperature in the combustion chamber. The replacement share depends from wood chips moisture content. The calorific value of syngas can be also up to ten times lower than calorific value of natural gas. Operating characteristic of an annular shaft kiln is huge air ratio in lower combustion chambers (λ=2.5–3) and simultaneously high combustion temperature. Therefore we can not replace large share of natural gas with low calorific syngas. Approved method of counter current gasification is predicted for wood chips gasification. As an oxidizer a ~10 % oxygen mixture of fresh air and flue gas will be used.

6. REFERENCES

[1] Boynton R. S., Chemistry and Technology of Lime and Limestone, John Wiley & Sons, New York, Second edition, 1980

[2] Oates J. A. H., Lime and Limestone, Wiley-VCH, Weinheim, 1998

[3] Letopis 2008, Statistični urad Republike Slovenije, http://www.stat.si/letopis

[4] Meier A., Solar Production of Lime – Final Report, January 2004, Paul Scherrer Institut (PSI), Solar Process Technology, CH-5232 Villigen PSI, Switzerland, 2004

[5] Stirling DK, The ecological plant in Castel d'Aiano. The CHP system of Castel d'Aiano school campus: wood chips gasification and Stirling engine, http://www.stirling.dk

[6] SimTech, IPSEpro Process Simulation Environment, System version 4.0, Graz, Austria, 2003

[7] Thomas H. P., Grenzen des Wärmeverbrauchs beim Brennen von Kalk in Ringschachtöfen, Zement-Kalk-Gips, 34/1, 1981, 27-35

AUTHOR ADDRESS

Assoc. Prof. Dr. Andrej Senegačnik

Faculty of Mechanical Engineering
Aškerčeva 6
SI-1000 Ljubljana
e-mail: **andrej.senegacnik@fs.uni-lj.si**