FEASIBILITY STUDY OF COMBINED FIRING IN ANNULAR SHAFT KILN FOR LIME BURNING

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ABSTRACT

The article deals with combined firing of wood chips and natural gas in the annular shaft kiln for lime production. Wood chips are gasified separately in the autonomous gasifier. Hot syngas from the gasifier is mixed with natural gas in the existing combustion chamber and then burned completely. 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 up to 50 % of natural gas supplemented with the wood syngas made from the fresh wood chips.

POVZETEK

Članek analizira možnosti izvedbe kombinirane kurjave zemeljskega plina in lesnih sekancev v obročni jaškasti peči za žganje apna. Kurjava lesnih sekancev se izvede ločeno v samostojnem predkurišču, kjer se lesni sekanci uplinijo in delno zgorijo. Nastali vroči lesni pirolizni plini se dovajajo neposredno v obstoječo zgorevalno komoro kjer dogorijo skupaj z zemeljskim plinom. Količina in kurilnost nastalega lesnega plina je odvisna od vlažnosti lesnih sekancev. Simulacija kombinirane kurjave zemeljskega plina in lesnih sekancev v spodnjih gorilnikih peči pokaže, da je s svežimi lesnimi sekanci možno nadomestiti do 50 % zemeljskega plina.

1. INTRODUCTION

Lime burning is a several thousand years known procedure. The usage of lime in the living environment doesn't have any negative impacts, therefore the production of lime is still increasing. Use of lime is not limited just in civil engineering. Technology of lime burning was improving specially in the 50's of the last century and a huge energy consumption decrease was achieved [**Error! Reference source not found.**, **Error! Reference source not found.**]. The lime burning industry needs a high temperature heat, over 900 °C. 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 house effect, CO_2 tickets, manufactures are looking for alternative (cheaper) fuels, also renewable [**Error! Reference source not found.**]. In northern 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 the equipment. In this article we treat a cheaper method of wood consumption. That consists of separate industrial pre-furnace/gasifier where wood chips are gasified. Hot pyrolitic gases are duct directly to the existing combustion chamber where burned completely together with the natural gas. With this kind of combined firing up to 50 % of natural gas can be replaced with fresh wood chips syngas co-firing.

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. It is then 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.

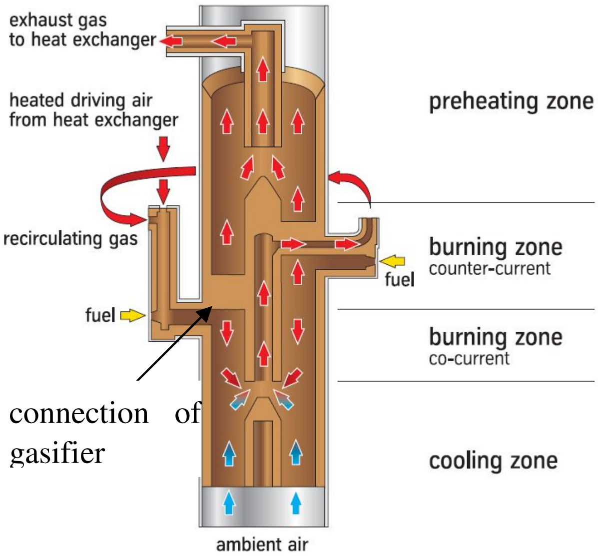

Figure 1: Annular shaft kiln for lime burning

3. PRE-FURNACE – GASIFIER

For the pre-furnace/gasifier a typical industrial application from hat water heating systems is used [**Error! Reference source not found.**]. The pre-furnace/gasifier is updraft and therefore quite insensitive for the wood moisture. Hot pyrolitic gases from the gasifier are duct directly to the lower combustion chamber where they are burned completely together with the natural gas. There is no additional loss at wood firing because the syngas is used directly and is not intercooled. Due to larger outer surface only the radiation losses are increased a bit. At the kiln there is some hot waste air, ~200 °C, which can be used as driving air for the gasifier.

Figure 2: Industrial wood chips pre-furnace/gasifier. Typical application for hot water heating systems [**Error! Reference source not found.**]

4. COMBINED WOOD CHIPS NATURAL GAS FIRING

Fig. 3 shows the adiabatic flame temperature of dry and fresh wood chips combustion. The temperature of combustion air is 700 °C and air ratio is 2.7 i.e. the process parameters from the kiln.

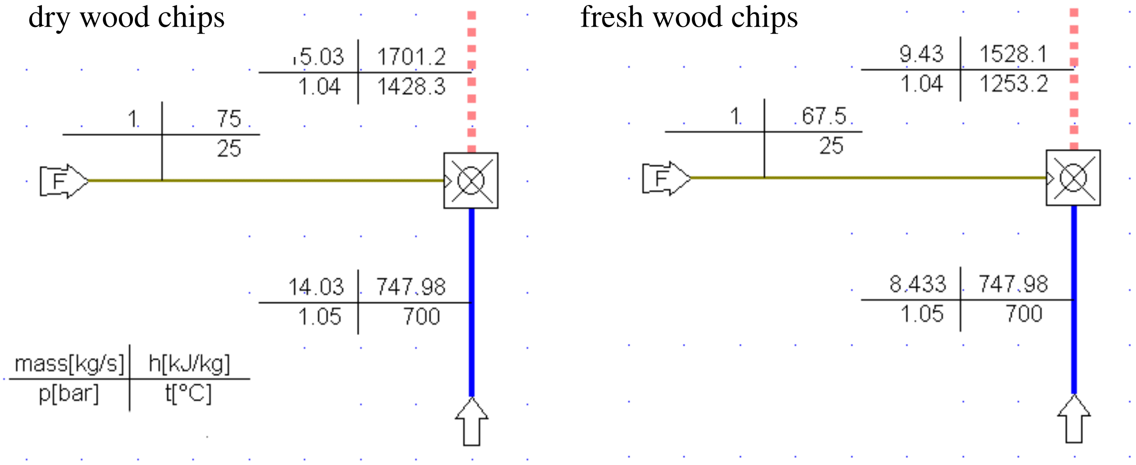

Figure 3: Adiabatic flame temperature comparison; dry and fresh wood chips, air ratio 2.7

In a case of fresh wood chips combustion the adiabatic flame temperature is 1253 °C. In a view of kiln's process parameters this temperature is to low. Fresh wood chips can not completely replace natural gas. In a case of dry wood chips combustion we achieve 1428 °C which is enough for complete replacement of natural gas. Lime kilns from the Northern Italy which are fired by dry pulverized wood confirm this fact.
Flame temperature calculations were performed with the wood chips composition given in Tab. 1.

Table 1: Wood chips composition

		dry wood chips	fresh wood chips
carbon	mas. %	43.5	26.2
hydrogen	mas. %	5.2	3.1
oxygen	mas. %	37.9	22.8
water	mas. %	12.5	47.4
lower heating value	MJ/kg	15	8.1

Energy and mass flow balance of lower combustion chambers is given in Fig. 4. Figure represents the combined firing of fresh wood chips and natural gas. Process was simulated with the software package IPSE-Pro 4.0 [**Error! Reference source not found.**]. Results on Fig. 4 are given for kiln's load 150 t per day. The share of natural gas was 50 % and fresh wood chips 50 %.

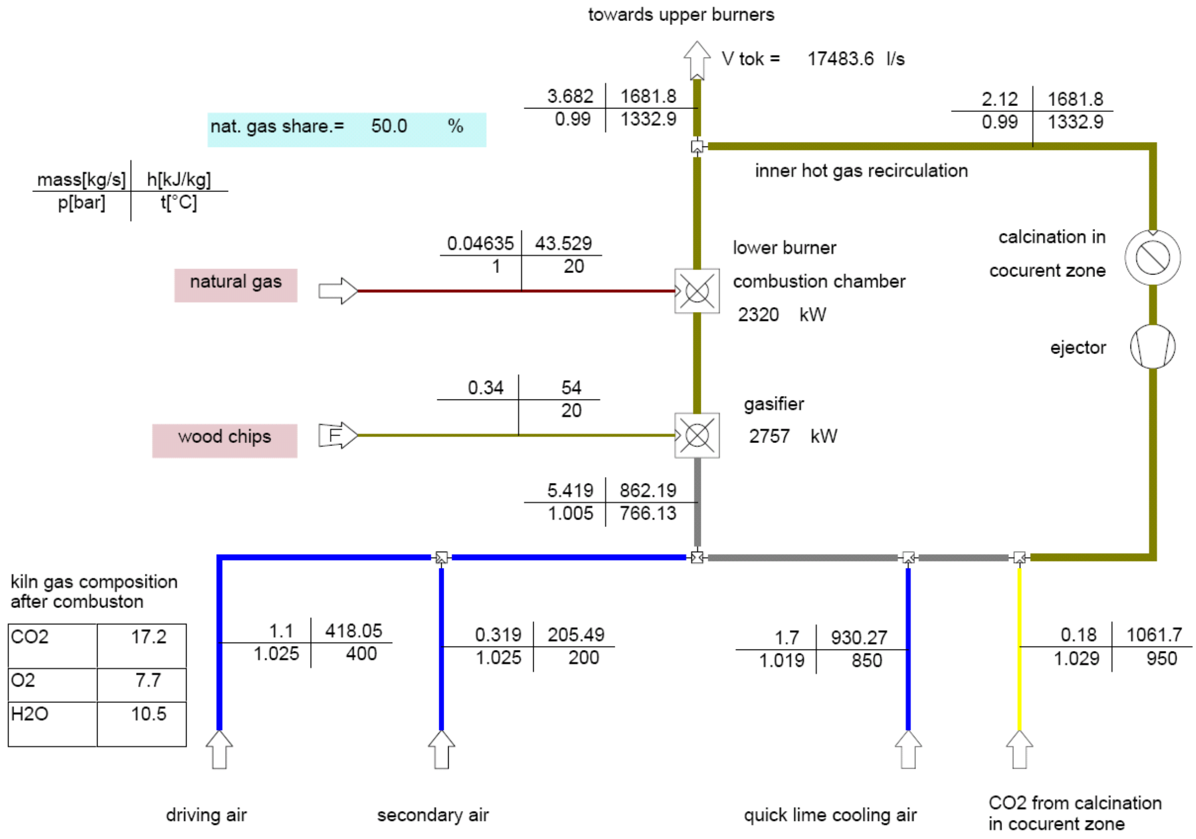

Figure 4: Model of lower combustion chambers

In the process simulation we observe kiln parameters by increasing the share of fresh wood chips. 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.

Secondary air is primarily used for the natural gas distribution in the combustion chamber and the combustion (process) temperature regulation. Pre-furnace/gasifier also requires some air – minimal 25 % of stoichiometric amount. Therefore the amount of available air for the gas burner will be reduced. The upper limit of secondary air reduction is 90 %. We suppose that min. 10 % of secondary air is still needed to avoid burner's overheating.

Simulation results of combined firing are given in Tab. 2. With fresh wood chips co-firing we can replace up to 50 % of natural gas. Co-firing also slightly affects some other kiln parameters like the kiln gas composition – CO_2 and H_2O increase, O_2 decrease. Due to increased water vapor the specific heat c_p of kiln's gas is also increased. Increase of kiln's gas c_p consequently requires higher heat input by fuel if the same process temperature should be maintained.

From Table 2 it is clear that offside is reached at 40 % share of natural gas. Kiln's gas mass flow is too big and the temperature is too low. The amount of air used in gasifier is increased and consequently lack of distribution/cooling air for gas burner appears.

Table 2: Combined firing of natural gas and fresh wood chips

natural gas share	%	100	60	50	40
combustion temperature	°C	1333	1325	1333	1298
mass flow of kiln gas	kg/s	3,609	3,603	3,682	3,723
kiln gas composition - CO2	mas. %	12,0	15,9	17,2	17,1
kiln gas composition - O2	mas. %	10,9	8,7	7,7	8,2
kiln gas composition - H2O	mas. %	6,7	9,5	10,5	10,4
total heat power	kW	4640	4812	5077	4856
heat power – nat. gas	kW	4640	2784	2320	1856
haet power – wood chips	kW	0	2028	2757	3000
gasifier air	kg/s	0	0,195	0,266	0,289
wood chips mass flow	kg/h	0	900	1225	1332
natural gas burner cooling air	-	YES	YES	YES	NO

5. CONCLUSIONS

The paper treats the ability of combined firing at the annular shaft kiln for lime burning. A study of additional, separate pre-furnace/gasificator installation is made. Hot pyrolitic gas from the wood chips gasifier are mixed and burned together with the natural gas in the existent lower combustion chamber. Share of wood chips firing strongly depends upon their moisture content. In case of dry wood chips usage, a total replacement of natural gas is theoretically possible. If the fresh wood chips (~50 % moisture content) are used approximately a 50 % of natural gas can be replaced.

The simulation of combined firing shows, that two technological limitations appear almost at the same time when over 50% of natural gas is replaced. The first one is too low temperature in the combustion chamber and the second is lack of secondary air for gas burner cooling. Air lack appears due to air usage for the gasificator.

The main reason for the combined firing modification is to reduce the production expenses using cheaper fuel – wood chips and also to save at CO_2 tickets. Operating experience will give the answer how the minimal changes of process parameters such as modified flow dynamics in the combustion chamber, larger process temperature oscillations, increased CO_2 and H_2O content in kiln's gas etc., affect the lime quality.

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

[4] Topling, http://www.topling.com/index.php , marec 2011
[5] SimTech, IPSEpro Process Simulation Environment, System version 4.0, Graz, Austria, 2003
[6] Thomas H. P., Grenzen des Wärmeverbrauchs beim Brennen von Kalk in Ringschachtöfen, Zement-Kalk-Gips, 34/1, 1981, 27-35

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