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WOOD SYNGAS AS CO-FUEL IN INDUSTRIAL FURNACES

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ABSTRACT

One of options to reduce greenhouse-gas emissions is the use of renewable energy sources, including wood biomass. Wood biomass is not directly usable as a fuel for most of industrial furnaces. Nevertheless biomass can replace a certain portion of the fossil fuel by means of a gasifier where biomass is gasified with air. Resulting combustible wood syngas is then collected and introduced to the furnace to replace a portion of fossil fuel energy. Fossil fuel replacement ratio is strongly influenced by the composition and thermodynamic and transport properties of wood syngas which depend strongly on biomass composition, especially moisture content. For the operation of heating systems requiring low-temperature heat only the quantity of energy released by the combustion is relevant. For proper operation of the furnaces requiring high temperature heat, for example lime burning or melting of metal besides the quantity of energy many other parameters are also important: temperature of the resulting flue gas, thermodynamic and transport properties of the flue gas, the flue-gas mass flow, etc. Because of these limitations generally we cannot completely replace fossil fuels with wood biomass. The article analyzes the impact of biomass composition on the properties of wood syngas and it's suitability to partially replace fossil fuels in some industrial furnaces

Keywords: wood chips, gasification, flue gas

1. INTRODUCTION

The transition from fossil fuels to renewables is one of the goals of world's energy politics. One of realistic options is to gradually increase use of wood as a fuel. Wood biomass is not directly usable as a fuel for most of industrial furnaces. Nevertheless biomass can replace a certain portion of the fossil fuel if it is gasified prior to burning. The easiest and the cheapest way is an external gasification unit with the addition of air. The combustible wood syngas is then collected and introduced to the furnace for final combustion without any intermediate cooling or cleaning. This way all wood energy is transferred to the furnace. The advantage of such system is that only minimal modification of existing firing system is required. Normally there are limitations that cannot be neglected [1]. This article deals with some specific flue gas properties which affect the extent to which fossil fuel can be replaced by wood.

In this study some specific properties of the flue gases originating from four different fuels, i.e. natural gas, light oil, dry wood chips and moist/fresh wood chips will be considered. Some important factors are not discussed here: composition of wood specially the moisture content, granulation of fuel, dust particles in the syngas, flying ash, slag, heat regeneration, internal mass flows etc.

2. FLUE GAS PROPERTIES

During any fuel-replacement project it is essential that basic parameters in the furnace and heat-transfer surfaces do not change significantly. Some of these parameters are flue-gas heat content, temperature, volume and mass flow. At high temperature applications involving thermal radiation also radiation constants are important. In some industrial processes like lime production and metal or minerals melting only high temperature heat is required. For example lime burning requires only the heat between 830 °C and 1300 °C [2]. Figure 1 shows an example of annular shaft kiln for lime burning. First part of combustion air is introduced to the kiln from the bottom. It takes the heat from the lime which is moving downwards. The second part of combustion air comes from regenerative heat exchanger and is used for driving ejectors. Less than 20 % of total air is introduced directly to burners. If we want to replace a portion of fuel oil or natural gas with synthetic gas coming from biomass gasification some limitations apply. The first limitation is the preservation of flue-gas mass flows and their ratios. The second limitation is the preservation of flu-gas-temperature level and the third is vertical temperature profile of the kiln. Even though process measurements do not show significant changes of parameters the process in the kiln is changed due to changed flue-gas properties.

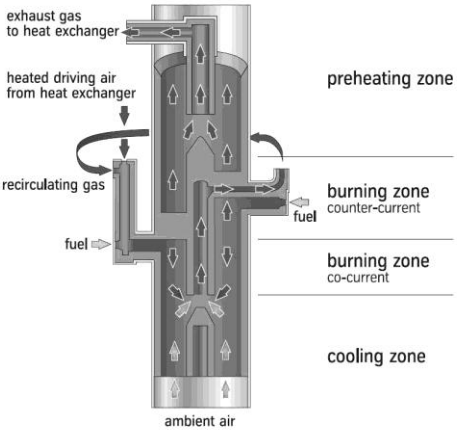

Figure 1. Annular shaft kiln for lime burning [3]

Let us examine some of characteristic properties of flue-gas that is formed during combustion of different fuels with air ratios λ = 1 and λ = 2. *Table 4* shows heat $\Delta h = h_{1300} - h_{830}$ released from 1 kg of flue-gas between 1300 °C and 800 °C and the gas constant R. The usual compositions of fuel oil and natural gas are used for calculations. Moisture contents of 12,5 % and 47,4 % are used for driy and moist wood respectively.

Table 4. Heat content and gas constant of flue gas

	λ = 1		λ=2	
	Δh	R	Δh	R
	kJ/kg	kJ/(kg K)	kJ/kg	kJ/(kg K)
wood dry	641,8	284,7	606,2	286,3
wood moist	694,2	301,8	638,0	295,9
natural gas	654,0	300,6	610,3	294,6
oil light	627,2	286,9	596,5	287,6

If Δh values from *Table 4* are sorted by size and expressed in a relative manner the first four columns of *Table 5* are obtained. Flue gas from moist-wood has the biggest Δh which is due to high water content (*Figure 3*). Due to ideal-gas law specific volumes v are proportional to gas constants. Flue gas from wet wood has the biggest specific volume while flue gas from dry wood has the smallest. Specific volume is also important for the flue-gas velocity and consequently heat-transfer coefficient [4, 5, 6] and pressure losses. If Δh is divided by R a quantity proportional to specific heat capacity c_p is obtained (last two columns in *Table 5*).

Table 5. Relative heat content, specific volume and specific heat capacity

	$\lambda = 1$	$\lambda = 2$	$\lambda=1$	$\lambda = 2$	$\lambda=1$	$\lambda = 2$	$\lambda=1$	$\lambda = 2$
	Δh	Δh	Δh_{rel}	Δh_{rel}	v_{rel}	v_{rel}	$c_{\mathrm{p,rel}}$	$c_{\mathrm{p,rel}}$
	kJ/kg	kJ/kg	%	%	%	%	%	%
wood moist	694,2	638,0	100,0	91,9	100,0	98,1	100,0	93,7
natural gas	654,0	610,3	94,2	87,9	99,6	97,6	94,6	90,1
wood dry	641,8	606,2	92,4	87,3	94,3	94,9	98,0	92,0
oil light	627,2	596,5	90,3	85,9	95,1	95,3	95,0	90,2

- Available heat content Δh: flue gas from moist wood contains more heat than flue gas from other fuels. The smallest heat content is in flue gas from fuel oil. If air ratio increases heat content decreases. This effect is the most obvious in the case of moist wood and the least obvious is in the case of fuel oil: if λ increases from 1 to 2 Δh decreases for 8,1 % and 4,9 % respectively. The decrease of Δh is mainly caused by decreased water content in flue gas (*Figure 2* and *Figure 3*).

- Specific volume v: dependence of specific volume on type of fuel and air ratio is important for maintaining the flue gas velocity through the furnace. Velocity has great impact on convective heat transfer and pressure losses especially if flue-gas ducts are irregularly shaped or flue gas passes through layers of granulate: lime burning, stone-wool production [7]. The dependence of specific volume on air ratio is the most significant in the case of moist wood and natural gas (~ 2 %), and less significant in the case of dry wood (~0,6 %) and fuel oil (0,23 %). Flue gas from moist wood also has the biggest specific volume while flue gas from dry wood has the smallest specific volume. Again water content is the most significant factor for this phenomenon

- Specific heat capacity c_p: c_p is the biggest in the case of moist wood and the smallest in the case of natural gas. During increase of air ratio λ from 1 to 2 c_p decreases for 5 % to 6 % in all cases.

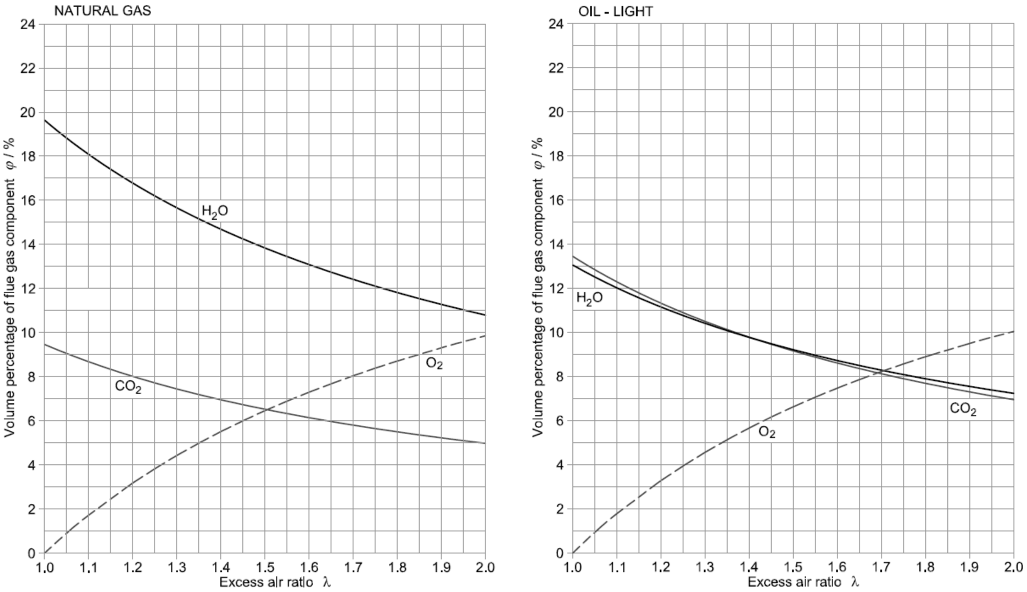

Figure 2. Flue gas composition from natural gas and light oil [5]

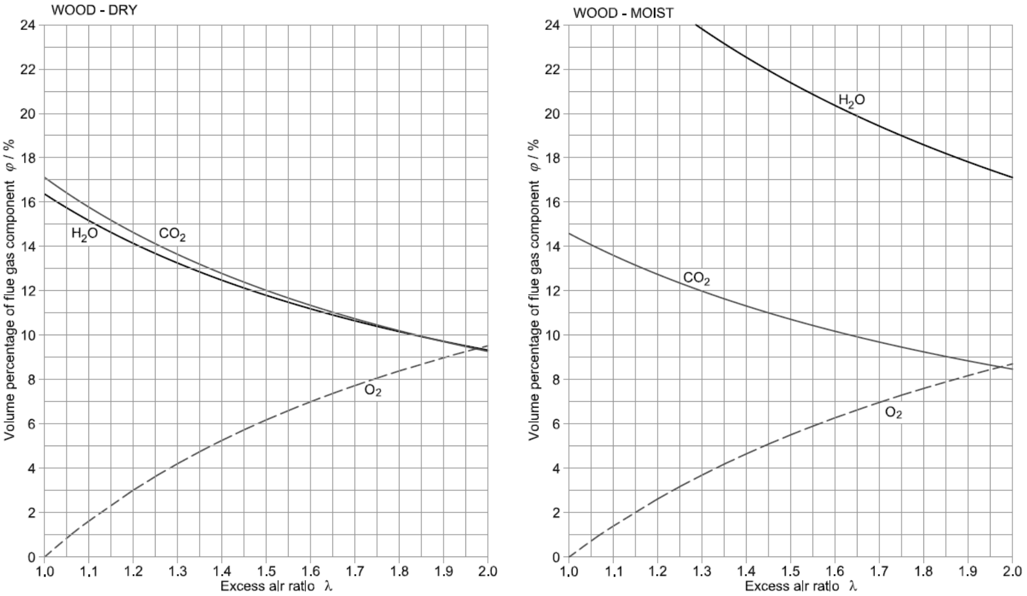

Figure 3. Flue gas composition from dry wood and moist wood [5]

3. CONCLUSIONS

Paper deals with some of basic thermodynamic properties of flue gas formed during combustion of natural gas, light fuel oil, dry wood and moist wood. Three parameters were observed: heat content, specific volume and specific heat capacity. Their absolute values were compared and their dependence on air ratio was analyzed. Besides heat content also the differences in flue gas properties need to be taken into account if fossil fuel is to be completely or partially replaced with wood biomass. It is important that the intensity of heat transfer, temperature profile and pressure losses remain within allowable boundary values.

The first impression is that flue gas from moist wood seems to be the most appropriate but due to high water content flame temperatures are relatively low and stack losses are high. During the modification of annular shaft kiln with addition of external wood-chips gasifiers became evident that water content in wood is of great importance: in moist-wood case ~40 % and in dry-wood case ~70 % of fossil-fuel supplied to bottom-level burners can be replaced.

Many factors must be taken into account such as fuel price and its availability, fuel properties, flue-gas properties, technology of the furnace etc. to maintain constant parameters of the process and good quality of the product after intended total or partial replacement of original fuel with any other alternative fuel.

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