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Influence of the Gasifiing Agent on the Biomass Gasification Process

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Abstract: The biomass is one of the most important participants in the global transition from traditional fuels such as coal, oil and natural gas to carbon-neutral fuels, as well as in the fight to reduce global warming. To conduct a detailed study of gasification processes, a thermodynamic equilibrium model was developed and numerically implemented, which calculates the composition of a gasifying agent and the composition and quantity of the resulting gas. This software-implemented thermodynamic equilibrium model can be used for different types of gasifiers as well as for different types of biomass.

Keywords: *gasification, biomass, mathematical model, thermodynamic equilibrium model, gasifying agent*

1. Introduction

Renewable energy sources are alternatives to fossil fuels that contribute to reducing greenhouse gas emissions, diversifying energy supplies, and reducing dependence on unreliable and volatile fossil fuel markets, especially oil and gas [1]. European Union legislation to promote renewable energy sources has developed significantly over the past 15 years. In 2018, a target of a 32% share of renewable energy sources in energy consumption in the European Union by 2030 was agreed. In 2021, in view of the European Union's new climate ambitions, the co-legislators were proposed to revise the goal of 40% by 2030 [2].

On 11 December 2019, the Commission presented its Communication on the Low Green Pact (COM(2019)0640). This Green Pact sets out a detailed vision to make Europe climate neutral on the continent by 2050 by supplying clean, affordable and secure energy [2].

Biomass is expected to be a primary source of energy in the future. It is one of the most important participants in the world's transition from more popular fuels such as coal, oil and natural gas to carbon-neutral fuels, as well as in the fight to reduce global warming [3].

The optimal conversion of chemical energy from biomass or other solid fuels into the desired gas or liquid depends on the correct configuration, sizing and selection of operating conditions of the gasifier. Simulation or mathematical modeling of the gasifier allows the designer or engineer to intelligently optimize the operation or design of the plant using available pilot plant experimental data. Through simulations, operational limitations and hazardous or undesirable operational areas, if any, can also be determined. Mathematical modeling provides a less expensive assessment of benefits and associated risk [4].

The thermodynamic equilibrium model predicts the maximum possible yield of the desired product from the reacting system. In other words, if the reactants are allowed to react long enough, they will reach equilibrium. [5].

2. Experiment

To create a thermodynamic equilibrium model for biomass gasification, a system of equations is solved: determining the composition of the gas phase (material balance) and energy balance. When determining the composition of the gas phase in the gasification process, the hydrogen and oxygen from the moisture of the biomass and the air supplied to the process are included in the material balance. To determine the composition of the gases in the biomass gasification process, the atomic balance of carbon, hydrogen, oxygen and nitrogen is done at (ER) < 1 [6].

For the given biomass chemical analysis, air temperature and gasification temperature of the produced gas, combining the mass balance equations with the equilibrium constant equations and the energy balance equation, the equivalence ratio (ER), quantity, composition and calorific value can be determined of the obtained gas, on the basis of which the supplied amount of the gasifying agent and the type of the gasification process can be determined.

Wood chips with the following dry mass composition were selected as biomass [7]:

$C^C = 49.9$ %; $H^C = 6$ %; $O^C = 42$ %; $N^C = 0.5$ %; $A^C = 1.6$ %; $W^P = 15$ %

The studies were conducted under the following conditions:

- Air temperature 20 °C
- Amount of supplied oxygen was set: 21%, 30%, 40% and 50%
- Amount of moisture was set: 5 %, 10 %, 15 % and 20 %
- Temperature after 1 degree of gasification 800 °C
- Final gasification temperature 1200 °C

3. Results and discussion

The gasification model described above was programmatically implemented and simulation studies were conducted at different parameter values to evaluate its effectiveness. This was done with the help of a specially developed algorithm of two-stage gasification, which was implemented programmatically.

Research results show that the amount of gases produced decreases with an increase in the amount of oxygen, because a smaller part of the biomass is burned, but the calorific value of the gas increases (figure 1 to 4).

The results also show that as the supply of oxygen-enriched air as a gasifying agent in the gasifier increases, the calorific value of the gas increases, while with air supply, the calorific value decreases because an additional amount of nitrogen, which is ballast, is added.

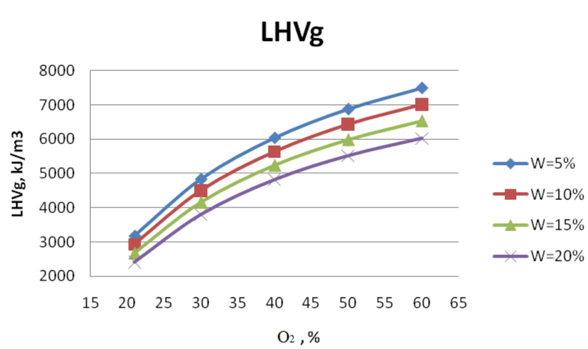

Fig. 1. Calorific value of wet gas

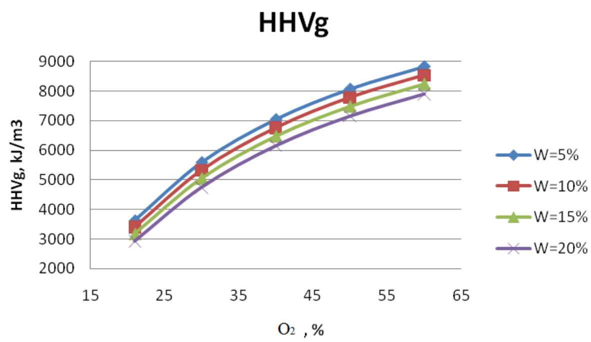

Fig. 2. Calorific value of dry gas

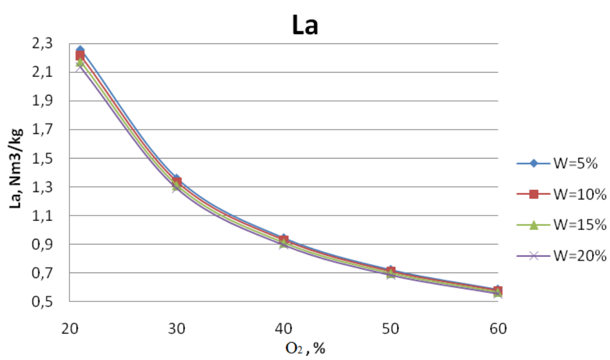

Fig. 3. Amount of air

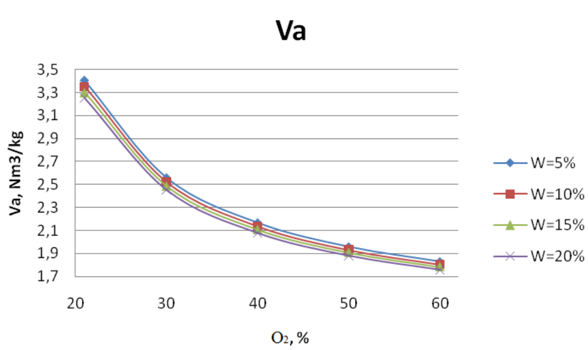

Fig. 4. Amount of gases

4. Conclusion

A thermodynamic equilibrium model for a two-stage regime of biomass gasification, including a material balance of the individual components of the biomass and an energy balance of the system, was developed and programmatically implemented. With its help, the composition of a gasifying agent and the composition and quantity of the resulting gas are calculated.

This software-implemented thermodynamic equilibrium model can be used for different types of gasifiers as well as for different types of biomass.

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