14th EUROPEAN CONFERENCE ON INDUSTRIAL FURNACES AND BOILERS

2 - 5 April 2024 - Algarve, Portugal

INFUB

Conference Agenda

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Authors

Session Overview

Session

20-BURN: Burners and Modelling

Time: **Friday, 05/Apr/2024: 09:25 - 10:45** *Location:* **Sala Galé I**

Session Chair: **Eva Gutheil**

Presentations

20-BURN: 1

Optimization of the plasma-assisted gasification process in a vertical entrained-flow gasifier through the CFD simulations

Robert Lewtak, Jonas Brandstetter, Sebastian Bastek, Johannes Waßmuth, Kentaro Umeki, Andrius Tamosiunas, Sebastian Fendt, Harmut Spliethoff

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The production and application technologies of hydrogen are currently becoming more prospective in relation to fossil fuels, the use of which causes high emissions of harmful substances into the atmosphere (including CO_2). In addition, the current energy crisis in the area of fossil fuels supports the development of energy technologies based on fuels obtained from emission-free sources. A promising technology for hydrogen production is the process of gasification of solid fuels (biomass waste, rdf, biomedical waste, hazardous materials, etc.) in a plasma-assisted gasification reactor. The mole fraction of hydrogen in the obtained syngas can reach up to 50%, which makes the plasma gasification technology a very versatile, ecological and safe method of hydrogen production.

One of the more important problems in optimizing the operation of an entrained-flow gasifier equipped with a plasma torch at the reactor top is to determine the location of the fuel supply points in the zone near the plasma in such a way as to ensure the best possible conditions for the gasification process and at the same time obtain high-quality syngas with a high carbon conversion of the feed material (high carbon conversion efficiencies). However, the gasification process is preceded by the processes of heating, moisture evaporation, devolatilization, i.e. release of volatiles with their further transformation (mainly homogeneous reactions), as well as the process of solid fuel fragmentation due to the high heating rate. In addition, an important aspect of the development of the gasifier is the ability to assess the residence time of fuel, gas flow pattern and mixing of particles and gas inside the reactor.

The paper presents the results of numerical simulations of the biomass flow and gasification process in a 2m high vertical entrained-flow gasifier equipped with a 30kW plasma torch. Several variants of the location of the fuel supply points in the plasma zone were adopted for the numerical simulations (e.g. particle injection by a one- and multi-point inlets with a non-swirl and swirl flow) and changes in the shape of the diffuser in the zone of the plasma torch. The obtained numerical results (e.g. velocity, temperature, particle trajectories, residence time, quality of the syngas) made it possible to select a one concept ensuring the most efficient gasification process. In the next stage, the selected concept will be implemented in a gas generator to carry out experimental work on the gasification process.

Acknowledgments

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20-BURN: 2

Spectral analysis of alternative low-carbon fuel combustion in plasma-assisted burner

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The glass industry is a fourth of energy-intensive industries in Europe. At least 70 % of the energy of this industry is produced from fossil fuel – natural gas. In order to meet EU goals to reduce greenhouse gas emissions by 55% by 2030, fossil fuels should be substituted with low/zero carbon fuels, e.g., biogas (CH4/CO2), etc. However, for two reasons, fossil fuel substitution with alternative ones could be challenging for energy-intensive industries like glass manufacturing. The first one: combustion of low or zero-carbon fuels results in entirely new combustion conditions, which in turn could reduce heat transfer by thermal radiation due to the low propensity to form soot in the flame, reduced concentrations of emitters and changes in flame emissivity; and the second: the glass industry involve high-temperature processes of raw materials conversion to glass melt, in which luminous and non-luminous radiation plays a significant role in the glass production and quality.

For this reason, plasma-assisted combustion can increase calorific value and feasibility. Complex research was carried out on the combustion of different calorific value gas mixtures (7.2 MJ/Nm3, 14.3 MJ/Nm3, and 21.5 MJ/Nm3) at various air excesses (α-1.2, 1.4, and 1.6) and the influence of plasma assistance in a new design burner for extremely low-calorific value gases. During experimental studies, the composition of combustion products (O2, CO, NOx, NO, and NO2) was determined, and the spectrometric characteristics of the flame (luminescence wavelengths) at different flame heights were analysed to investigate radiative properties. It was proven that the combustion of biogas containing 20% CH4 is possible only under plasma-assisting conditions. When using plasma, high intensities of active radicals, i.e., OH*, H2O*, O*, NH*, and C2* excitation spectra peaks, are formed in the combustion zone. It was investigated that plasma assistance, frequency, and air excess significantly influence the formation of the flame radiative properties and the composition of combustion products.

20-BURN: 3

Experimental Investigation of Flow Velocity in a Pulsation Reactor

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As the demands of transportation transformation continue to grow, there is a need for innovative material concepts to meet challenges such as e-mobility, renewable energy storage and the expansion of conversion capabilities. In this regard, highly efficient new catalysts can minimize exhaust emissions and thus avoid environmental and health problems. Pulsation reactors have proven to be exceptionally well-suited for the industrial scale production of oxide particles, such as novel catalysts, since the advent of the early 21st century. However, the design and optimization of pulsation reactors needs to consider factors such as fluid dynamics, mass transfer, and reaction kinetics to ensure efficient mixing and control of reactions. In this regard, the study of fluid dynamics plays a key role in optimizing reaction control by determining the appropriate fluid velocity range to achieve the desired reaction control. Fluid velocity directly affects reactant transfer rate, contact time and contact area. Therefore, for a comprehensive understanding of fluid velocity control in pulsation reactors, measurement studies are necessary to investigate fluid velocities under various operating conditions. In this study, an optical measurement method, particle image velocimetry (PIV), was used to measure and quantify the fluid velocity field inside the resonance tube of a Helmholtz-type pulsation reactor to gain insight into the average flow velocity and residence time of reactants under different operating parameters. In addition, the influence of the air-fuel equivalence ratio and power density input parameters on the flow velocity is investigated, as well as the existence of turbulent flow in the resonance tube and the uniformity of the fluid velocity distribution. Through these studies, our understanding of flow rate control and reaction time in pulsation reactors has been further expanded.

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20-BURN: 4

Liquid Fuel Evaporation under Entrained Flow Gasification Conditions – Insights for Burner Development

Manuel Haas[1], Sabine Fleck[1], Tobias Jakobs[1], Thomas Kolb[1,2]

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Processes for the conversion of waste based biogenic and anthropogenic feedstocks into platform chemicals are needed in order to achieve a transition from a linear to a circular economy with closed material cycles. High-pressure entrained flow gasification can serve as an enabling technology for a closed carbon cycle because of its ability to generate a high quality syngas from waste based fuels with a wide spectrum of contaminants, e.g. pyrolysis oil derived from mixed plastic wastes. Fuel conversion in the burner near region of entrained flow gasifiers is characterized by a complex interaction of different sub-processes that influence fuel conversion and syngas quality. In this work, liquid fuel evaporation in an entrained flow gasifier is assessed by measuring droplet size distribution, droplet velocity and liquid fuel concentration under reactive conditions as well as modeling in order to gain insights relevant for burner development for waste based fuels.

Experiments were performed at the atmospheric pressure Research Entrained flow GAsifier REGA at KIT, where monoethylene glycol was used as a model fuel under technically relevant gasification conditions. Two burner nozzles with different gas exit areas resulting in different gas momentum flows were applied. The gasification experiments were accompanied by cold experiments to obtain spray data under non-reactive conditions for comparison. The experimental results are complemented by simulations using a 2-phase free-jet model applying the D^2-law for modeling droplet evaporation [1,2].

Droplet size and velocity in the gasification experiment were measured along the jet axis by PDA. The results were used to investigate the evolution of droplet size distribution during the evaporation process as well as for calculating droplet residence times in the flame zone. In addition, a method for measuring liquid fuel concentration using fuel-tracer-LIF was applied. The method was validated under cold conditions and was then used to estimate liquid fuel concentrations under reactive conditions, followed by a detailed assessment of possible measurement errors.

Both experiment and model show a moderate increase in Sauter Mean Diameter (SMD) along the jet axis. This is explained by faster evaporation of small droplets, leading to an enrichment of larger droplets in the jet at larger nozzle distances which is clearly indicated by the droplet size distributions. Droplet residence times in the flame zone were on the scale of few milliseconds, leading to incomplete fuel evaporation in the flame zone. Significant differences in droplet residence time have been observed between the two nozzles investigated, originating from the different gas momentum at the nozzle exit. LIF

measurements and model calculation show that a decrease in droplet residence time leads to a reduced amount of fuel to be converted in the flame zone, giving a possible explanation for the formation of by-products.

[1] Hotz, C., Haas, M., Fleck, S., Kolb, T., Two-phase free jet model of an atmospheric entrained flow gasifier, Fuel, 2021, https://doi.org/10.1016/j.fuel.2021.121392
[2] Haas, M., Dammann, M., Fleck, S., Kolb, T., Entrained flow gasification: Impact of fuel spray distribution on reaction zone structure, Fuel, 2023, https://doi.org/10.1016/j.fuel.2022.126572

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