CO2 Gasification of Black Liquor Char under Isothermal and Dynamic conditions

Fernando Léo Bueno, José Luis Sánchez Cebrián

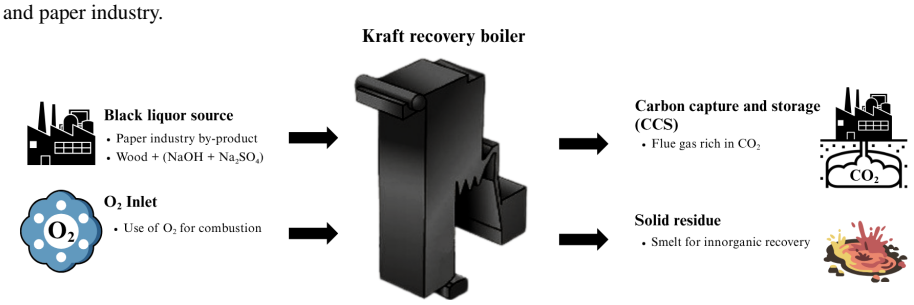
Grupo de Procesos Termoquímicos (GPT), Instituto de Ingeniería en Investigación de Aragón (I3A), Universidad de Zaragoza, Mariano Esquillor S/N, 50018 Zaragoza, España

Email: fleo@unizar.es

Instituto Universitario de Investigación en Ingeniería de Aragón
Universidad Zaragoza

Introduction

Black liquor, a key by-product of kraft pulping, is burned in recovery boilers to produce energy and recover chemicals. With growing interest in carbon-neutral technologies, integrating oxy-combustion into recovery boilers offers potential for CO_2 capture. To explore this, isothermal and dynamic gasification experiments were conducted on black liquor char to assess its reactivity under varying conditions. The data aims to support the development of a kinetic model for optimizing biomass-based CCS strategies in the pulp and paper industry.



Methodology

Figure 1 shows the system used for the gasification experiments, they were conducted in a vertical alumina tube reactor placed in an electric furnace, using both isothermal and dynamic conditions with temperatures ranging of 800–900 °C. Gas compositions was composed by varying concentrations of CO_2 and CO, balanced with N_2. The concentrations were continuously measured using a Rosemount BINOS100 analyzer.

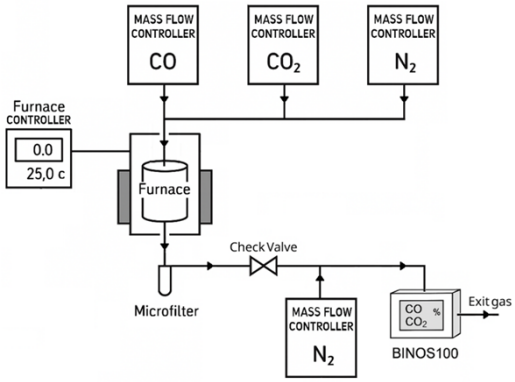


Figure 1 - Diagram of the experimental setup

Figure 3 shows two isothermal experiments conducted at fixed temperatures of 850 °C and 820 °C with identical gas compositions, these experiments showed a rapid increase in CO concentration following CO_2 introduction. Higher CO production in Iso-01 (~2.31%) compared to Iso-02 (~1.66%) indicates that reactivity increases with temperature. The results support the temperature-dependent nature of the Boudouard reaction and its role in CO formation.

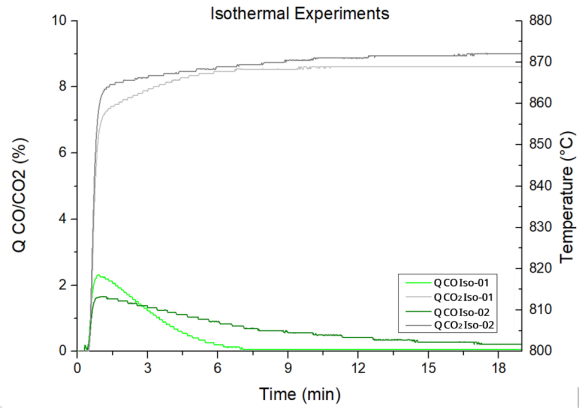


Figure 3 - Comparison between two isothermal experiments

Results

Figure 2 shows two dynamic experiments using different concentrations of gasifying agents. Upon CO_2 introduction, CO_2 concentration rose and then declined, while CO showed a corresponding peak, consistent with the Boudouard reaction ($C + CO2 \leftrightarrow 2CO$). The behavior followed temperature increases from 700 °C to 900 °C, suggesting that higher temperatures enhance CO production. The gas profiles stabilized toward the end, indicating a reduction in reactivity as char conversion approached completion.

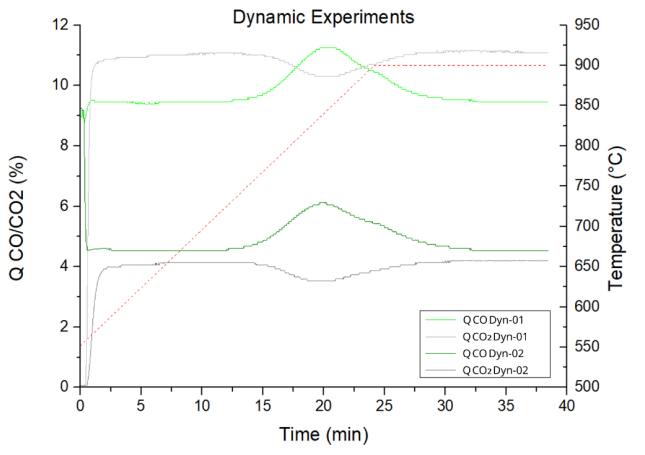


Figure 2 - Comparison between two dynamic experiments

Conclusions

Isothermal experiments, conducted at fixed temperatures, allow the assessment of the effect of temperature on CO production, demonstrating, in this case, that higher temperatures enhance the gasification reaction. In contrast, dynamic experiments, which involved a gradual temperature increase, captured the transient evolution of gas composition under conditions that could represent part of the recovery boiler reactions. The integration of both experimental approaches enables a comprehensive understanding of black liquor char behavior and serves as a robust foundation for the development of a future reliable kinetic model.

References

[1] BAJPAI, Pratima. *Biermann's Handbook of Pulp and Paper - Ray material and pulp making*. 3. Elsevier, 2018. ISBN 978-0-12-814240-0.

[2] VAKKILAINEN, Esa. *Kraft recovery boilers principles and practice Esa K. Vakkilainen.* Helsinki University of Technology, Energy Engineering and Environmental Protection, 2007. ISBN 9529186037

Acknowledgments

The authors wish to express their gratitude to the project: Oxy-Kraft recovery boiler - Towards novel integrated green energy parks (Project PCI2023-146009-2 funded by MCIN/AEI /10.13039/501100011033 and co-funded by European Union).