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Thermochemical conversion of wood pellets in a horizontal tube furnace: oxidation and pyrolysis

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Motivation

The search for sustainable and environmentally friendly energy sources has led to exploring biomass and biogenic residues as carbon-neutral alternatives to fossil fuels. Biomass encompasses a diverse range of fuels with varying elemental contents and distinct characteristics, influencing thermochemical conversion processes. Understanding the behavior of different solid fuels is crucial for optimizing energy production and mitigating the environmental impact.

One important aspect of solid fuel conversion is the transformation of carbon and nitrogen. Through processes like pyrolysis, gasification, and combustion, carbon is converted into valuable energy, while nitrogen compounds may be released as emissions. It is imperative to study these conversion pathways to ensure the efficient utilization of solid fuels and minimize the generation of nitrogen oxide (NOx) emissions.

The emissions of nitrogen oxides, particularly NOx, pose significant environmental concerns due to their harmful effects on both human health and the environment [1]. Hence, keeping NOx emissions at a minimum level is essential.

A horizontal tubular furnace is utilized to investigate the conversion behavior of various solid fuels and track the conversion of carbon and nitrogen. This experimental setup allows controlled conditions to study the characteristics of the fuels and their respective conversion processes.

In this study, we aim to delve into the intricate details of solid fuel conversion, focusing on the transformation of carbon and nitrogen.

Experimental Set-Up

The experiments are conducted at a horizontal tube furnace depicted in Figure 1. The furnace consists of an externally heated ceramic tube connected to steel fittings with inlets and an outlet.

General properties of the furnace and periphery:

- Furnace opening: 200mm diameter, 1000mm length
- The maximal temperature of 1700 °C
- Measurements: probe sampling and online gas analysis (NDIR)

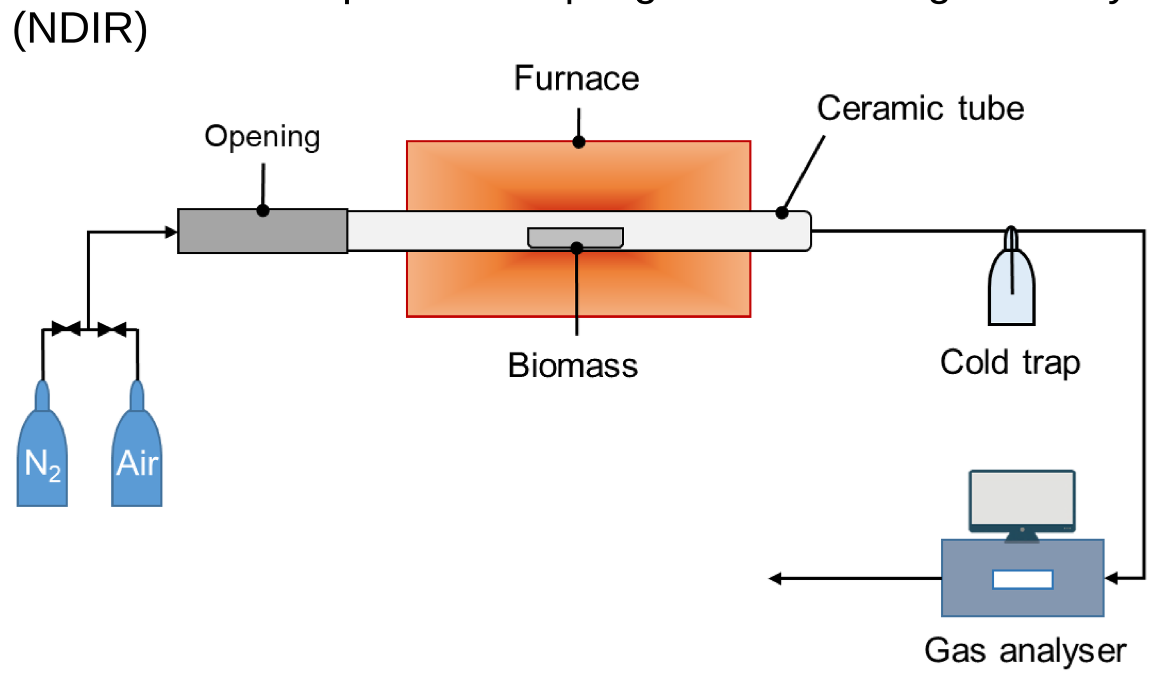

Figure 1: Schematic drawing of the horizontal tube furnace

Performed experiments

- Fuel: wood pencil shavings pressed into pellets
- Analysis of mass loss, proximate and ultimate analysis
- Temperatures ranged from 600 to 900 °C
- Experiments duration between 30 seconds and 10 minutes
- Air an nitrogen gas are used
- Crucibles with biomass were inserted into the furnace

Results

Table 1: Proximate and ultimate fuel analysis (ar)

C	46.4 %	O	37.0 %
H	6.32 %	w	6.59 %
N	0.71 %	a	0.35 %
S	0.04 %	Volatiles	78.2 %

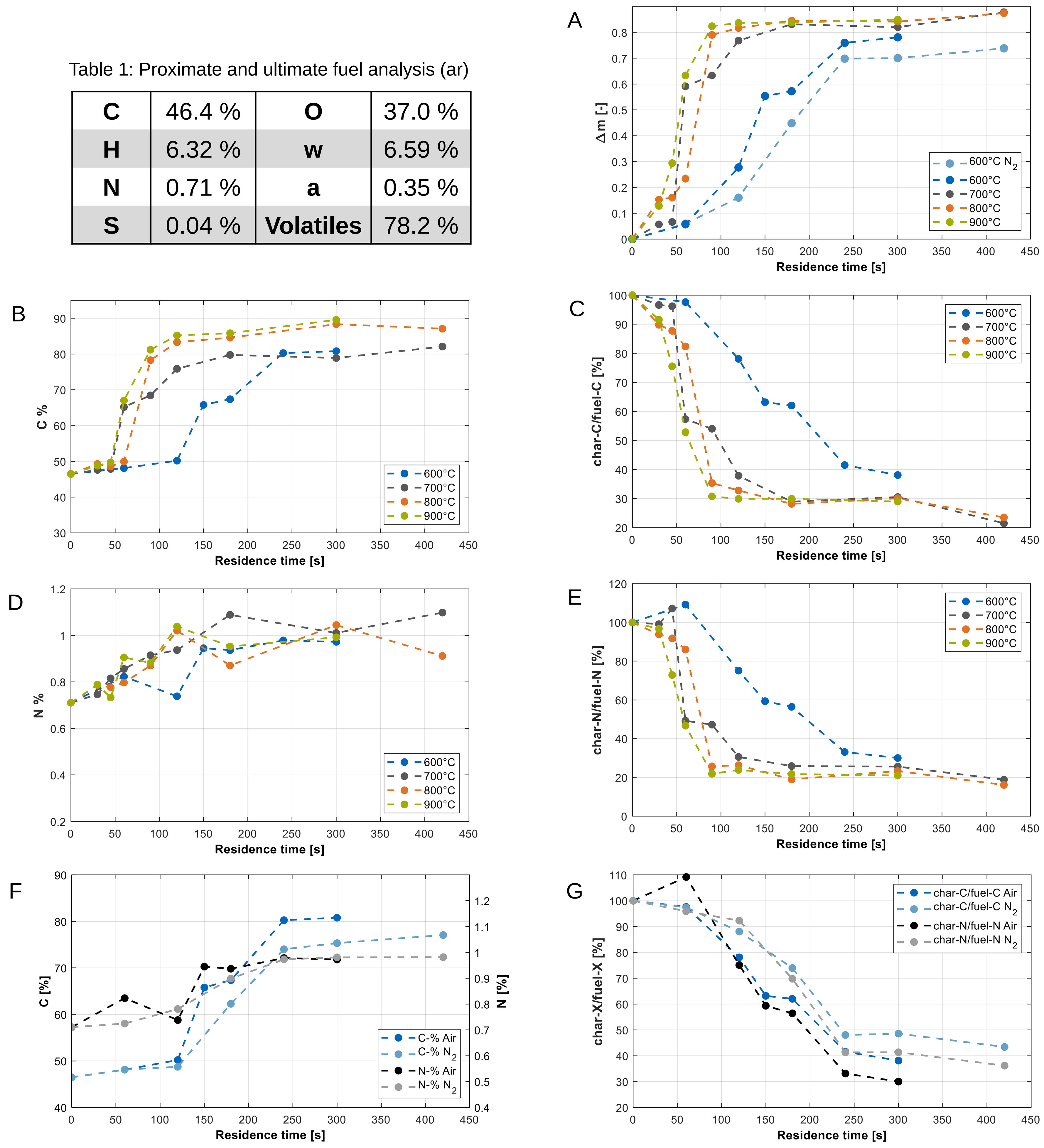

Figure 2: Mass loss over residence time (A), Carbon content in the sample (B), Carbon loss in the sample (C), Nitrogen content in the sample (D), Nitrogen loss in the sample (E), Carbon and Nitrogen content for experiments with air and nitrogen (F), Element loss in the sample with air and nitrogen (G)

- The proximate and ultimate analysis results are shown in Table 1
- The fuel conversion is dependent on the temperature, with increasing temperatures leading to an increase in mass loss (A)
- The carbon content of the solid samples increases substantially after a short period of time. Concurrent with the mass loss, which reflects the loss of volatiles leading to a coke sample (B)
- The nitrogen content of the samples increases slightly with the residence time (C)
- Most of the carbon and nitrogen in the sample are released with the volatile fraction (D and E)
- The presence of an oxidizing agent has an impact on the release of carbon and nitrogen from the solid fuel (F and G)

Conclusion

The experiments show that the temperature plays a significant role in the conversion rate of the solid fuel. The presence of an oxidizing atmosphere leads to an increase in conversion.

The nitrogen content of the samples increases with the residence time. However, most of the nitrogen was released with the volatiles. The oxidizing agent has also an impact on the release of the fuel-bound nitrogen, albeit not substantial.

Different fuels will be utilized with the same setup and will also be employed in an entrained flow combustion reactor to investigate the emissions of nitrogen oxides.

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[1] US Environmental Protection Agency: Integrated Science Assessment for Oxides of Nitrogen–Health Criteria.

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