EXPERIMENTAL DESIGN AND TESTING IN A PILOT-SCALE ROTARY KILN FOR THE TORREFACTION OF BEECH WOOD UNDER SYSTEM RESTRICTIONS

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Introduction

Torrefaction is a thermochemical process which concentrates the energy of the feedstock through partial degradation in the absence of oxygen. The main difference to slow pyrolysis is the final temperature, which is within a range of 200-325 °C.

The performance of torrefaction is measured through the Anhydrous Weight Loss (**AWL**), which can be directly correlated to the Low Heating Value (**LHV**) of the torrefied product.

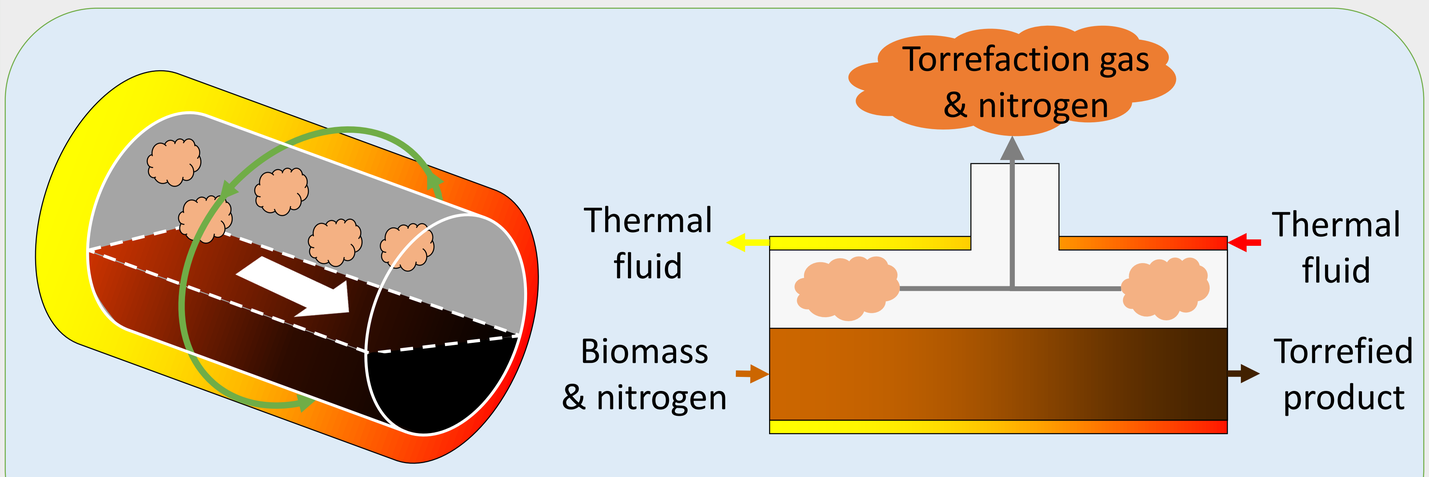
Objectives

The objective of this research is to establish correlations between torrefaction process parameters and AWL levels.

For this project, the AWL levels should be within a range 25-35 wt.% and the parameters to vary within the process are feeding rate, rotational speed and temperature.

System Description

The simulations and experiments were done in the plant at CENER in the **BIO2C facilities** in Aoiz (Spain). The main part of the process for torrefaction was a rotary kiln, whose schemes are shown in Figure 1 & 2. There is a scheme of the whole plant in Figure 3.



Figures 1 & 2. Scheme for the rotary kiln

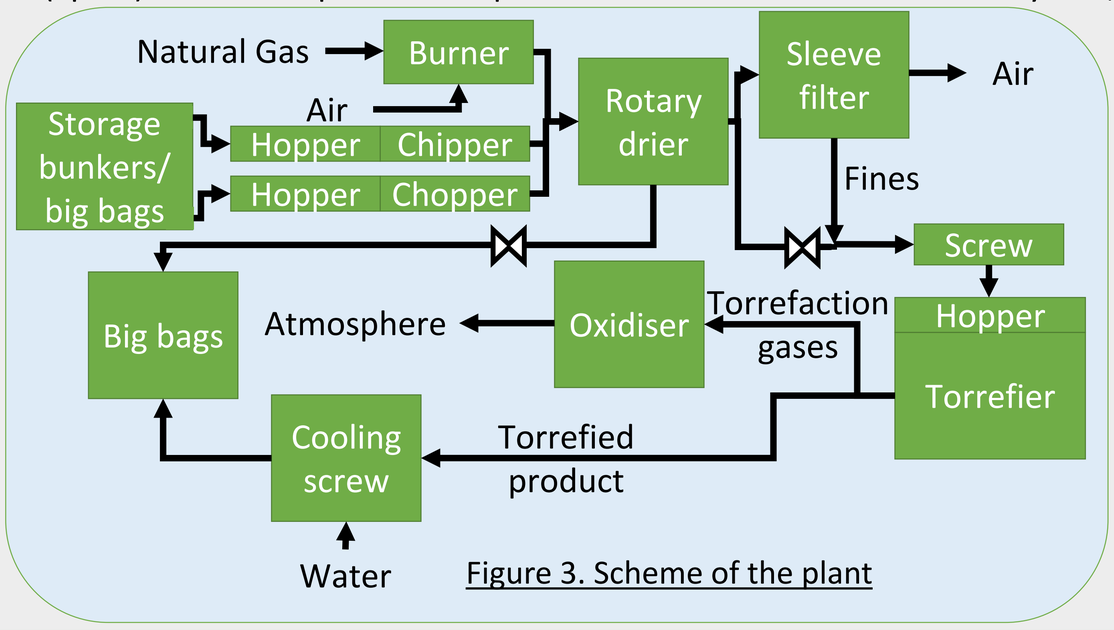


Figure 3. Scheme of the plant

Design specifications

The rotary kiln has two design specifications:

- Solids input: **200-500 kg/h**
- Reaction temperature: **240-310°C**

System

The torrefaction gases are extracted with a fan whose maximum torrefaction gas flow is **120 Nm³/h**

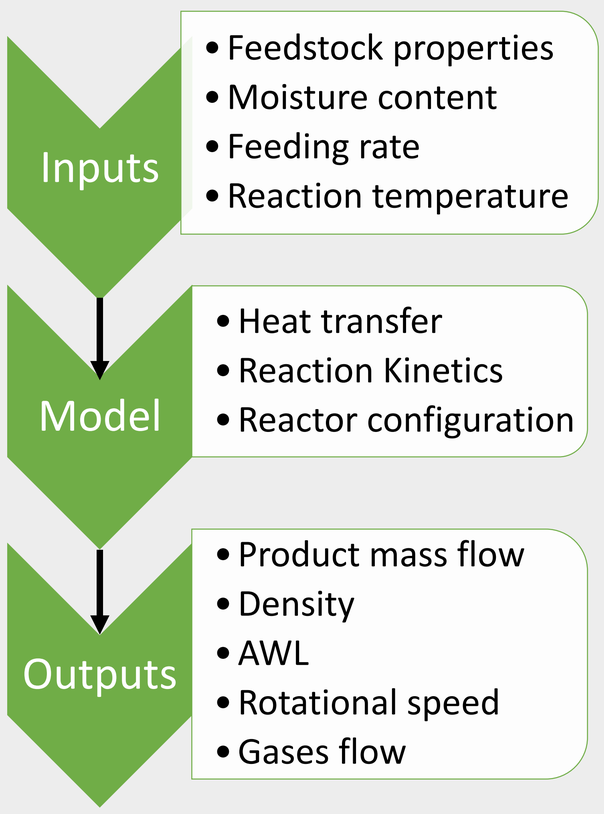
Restrictions

Three main restrictions:

- Range for the feeding rate
- Range for the reaction temperature
- Maximum torrefaction gases flow

To overcome the restrictions, simulations of the process are conducted prior to the actual experiments.

Simulation



Influence of parameters in the AWL

Several simulations were done to establish the parameters for the experiments. The temperature and feeding rate were varied to increase the AWL. The tendency of these parameters is explained in the following table

Temperature [°C]	Increase	It will increase the AWL and the torrefaction gases. It might drive to a excessive flow of gases to extract from the reactor.
	Decrease	The AWL and torrefaction gases decreases, it is a potential solution to overcome the restriction of the gas extraction.
Feeding rate [kg/h]	Increase	It reduces the AWL. However, it might not reduce the amount of torrefaction gases produced. When the feeding rate is increased, the total amount of moisture also increases, and can lead to a high flow of torrefaction gases when they are evaporated in the reactor.
	Decrease	The AWL increases because more heat can reach the particles in the reactor and produce more degradation but also more torrefaction gases

Results

Experiment 1: 300 kg/h and 260 °C
Experiment 2: 300 kg/h and 280 °C

		Experiment number			
		1		2	
		Model	Exp.	Model	Exp.
Thermal fluid	Outlet T [°C]	260	260	280	279.5
	Thermal fluid heat [kW]	66	58	70	73
Biomass	Type	Beech wood		Beech wood	
	Mass flow [kg/h]	300	300	300	300
	Density [kg/m3]	310	310	310	310
	Moisture content [wt.%]	9.9	9.9	9.9	9.9
Torrefied product	Mass flow [kg/h]	218	227	199	198
	Density [kg/m3]	325	330	345	355
	Exit T [°C]	243	234	252	251
	AWL [wt.%] (d.a.f.)	19.4	15.9	26.8	26.6
Gases	Exit T [°C]	219	224	229	225
	Flow [Nm³/h]	92	91	111	99

Conclusions

- The process is limited by different parameters whose origin is not always the reactor:
  - The reactor limits feeding rate and temperature range
  - Other parameters, such as the gas production in this case, could be limited by another piece of equipment within the system
- The AWL increased by 8 wt.% with an increase of 20 °C on the reaction temperature. This led to a further decomposition of the current feedstock (beechwood), and to an increase on the torrefaction gases production.
- The model matches accurately the behaviour of the reactor
  - Near the working limit, the accuracy decreases.
- There is not always a direct correlation between a parameter and its influence on the whole system. It might be direct correlation for a certain aspect of the system (AWL), but something completely different for others (gas production).

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the grant agreements 731101 (**BRISK2**) and Marie Skłodowska-Curie's 721991 (**GreenCarbon**).

The author wants to acknowledge CENER for its dedication during the time there. Also, special thanks to Inés del Campo (CENER) for all the help during the BRISK2 application process.