PYROLYSIS OF HAZELNUT SHELLS - TEAM 1.2

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Hazelnut Biochar Objective

- Design pyrolysis unit to produce biochar
- Constraints
  - *10,000 tons produced by Cascade Foods*
  - *September to April hazelnut processing period*
  - *Moisture content from 20-40% to 9%*

Background

- Oregon production - 65,000 tons
- Cascade Foods, LLC .
  - *Located in Albany Oregon, Cascade foods is one of the largest hazelnut processers in the United States.*
- Offers many products of hazelnuts including:
  - *Whole Kernel*
  - *Roasted*
  - *In-shell*
  - *Diced*
  - *Organic*

Biochar

- What is Biochar and why is it important?

Pyrolysis

- What is pyrolysis and why is it important?

Design Methodology

1. Perform preliminary research
   - Market research
   - Pyrolysis methodology
   - Develop design constraints
2. Brainstorm required design elements and potential design solutions
   - Operation mode
   - Methods of heat transfer
   - Required equipment
3. Run preliminary calculations to test validity of designs
   - Unsteady state heat transfer calculations
   - Reactor dimensions
4. Develop detailed design elements
   - Process control scheme
   - Perform safety analysis

Sample Calculations

<u>Assumptions:</u>

- Unsteady-state heat transfer, forced convection
- 1D HX in the x-direction of the shell
- No heat generation
- Constant properties during heating process
- Shell is thin enough to approximate as a shell
- Temperature bounds for heating: $T = 345°C$, $T_\infty = 350°C$, $T_o = 20°C$
- Temperature bounds for cooling: $T = 65°C$, $T_\infty = 20°C$, $T_o = 345°C$

<u>Calculations: Finding pyrolysis time for shells</u>

$$\frac{V}{A} = \frac{t}{2} \approx 0.65 \times 10^{-3}\ mm$$

$$Bi = \frac{h\left(\frac{V}{A}\right)}{k} = 0.0876$$

$$\frac{T - T_\infty}{T_o - T_\infty} = e^{-BiFo} \rightarrow Fo = \frac{-\ln\left(\frac{T - T_\infty}{T_o - T_\infty}\right)}{Bi} = 29.65$$

$$Fo = \frac{\alpha\, t_{pyro}}{\left(\frac{t}{2}\right)^2} \rightarrow t_{pyro} = \frac{Fo\left(\frac{t}{2}\right)^2}{\alpha} = 77.8\ s = 1.3\ min$$

<u>Calculations: Reactor Dimensions</u>

Assuming L/D ratio of 3, extra 20% volume for headspace

$$\frac{V_{day}}{2} = \frac{26.2\ tons}{2} = 11884\ \frac{kg}{batch} = 29.7\ \frac{m^3}{batch} \rightarrow 35.6\ \frac{m^3}{batch}$$

$$\boldsymbol{D = \sqrt[3]{\frac{4}{3\pi} V} = 2.47\ m}$$

$$\boldsymbol{L = 3D = 7.42\ m}$$

<u>Calculations: Batch Time</u>

$$t_{batch} = t_{heat} + t_{pyro} + t_{cool} + t_{transport/reset}$$

$$t_{heat} = \frac{350°C - 20°C}{5\ °C/min} = 66.0\ min$$

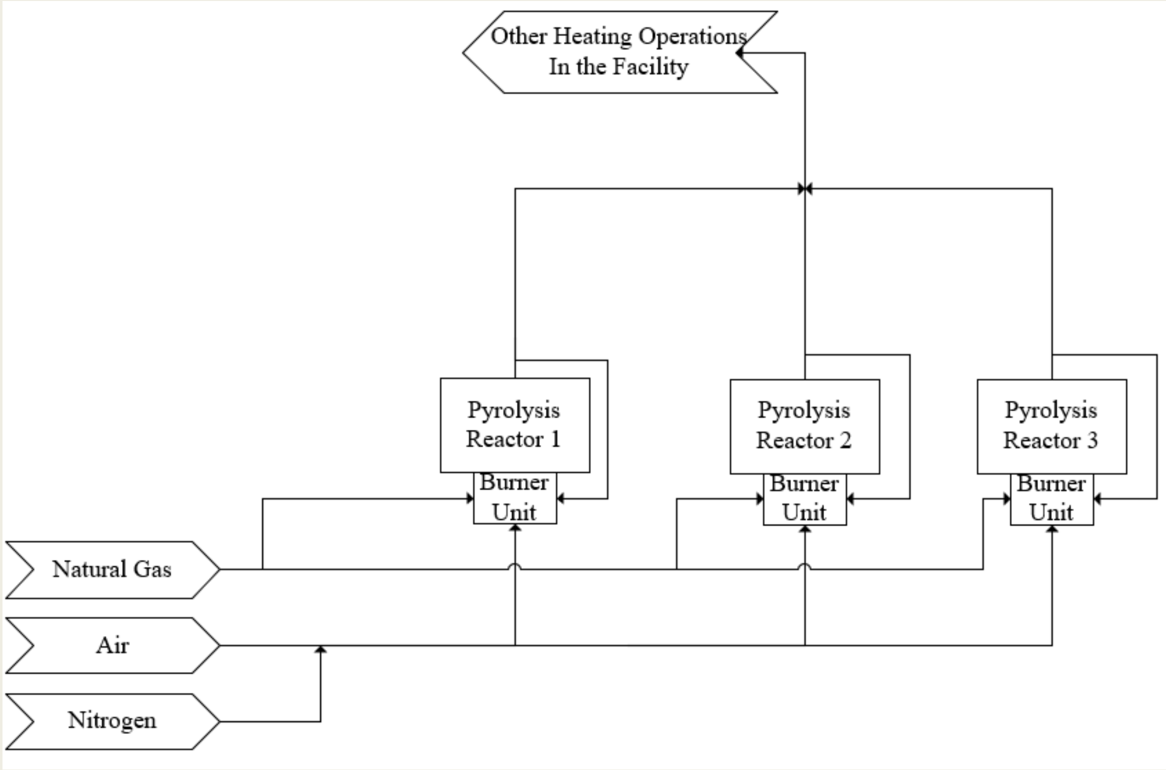
$$t_{pyro} = 78.1\ s = 1.3\ min$$

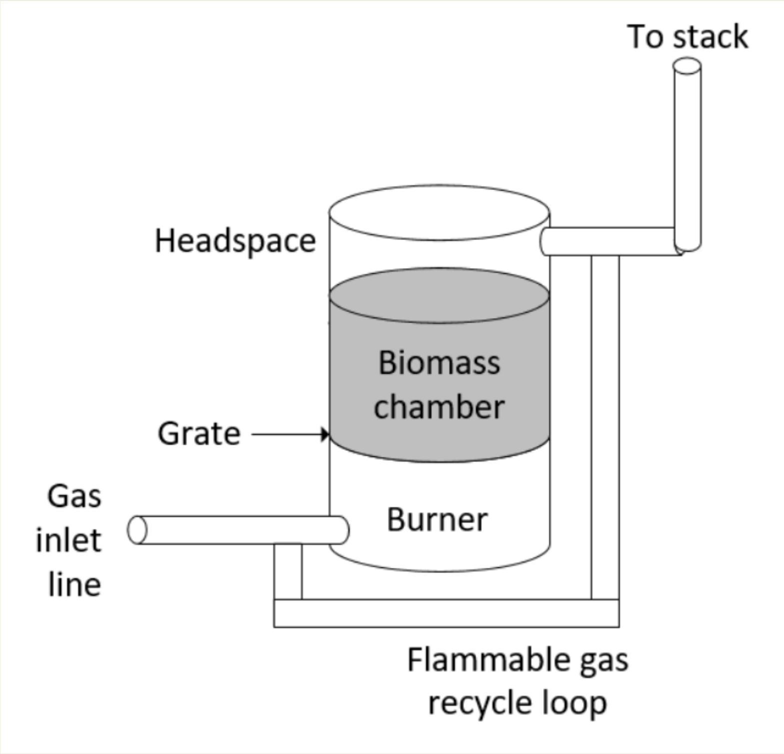
$$t_{cool} = 112.6\ s = 1.9\ min$$

$$t_{transport/reset} = 2\ hours = 120\ min$$

$$\boldsymbol{t_{batch} = 190\ min = 3.2\ hours}$$

Proposed Design





QUESTIONS?

Come to our Engineering Virtual Expo zoom room on June 4th, 2021 from 8:30-11:30am!