Municipal Solid Waste Feeder for Thermal Conversion

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Introduction

Background

Dr. Kevin Whitty, a distinguished chemical engineering professor, studies the process of converting hydrocarbon waste into energy. One reactor in his lab, an entrained flow gasifier, is a high pressure (300 psi) reactor which converts the waste into hydrogen and carbon monoxide (syngas). These gases are viable for the production of various industry products including jet fuel. Currently, the reactor input (feedstock) must be a 'pumpable' mass. This requires the lab to source a 'bioliquid' produced by a Canadian company from woody biomass. Thus, a more cost-effective and flexible feed system is required.

Problem

This project aims to create a stand-alone system which can feed various solid feedstocks directly into the 300psi gasifier while heating the feedstock to 150°C. These feedstocks should include sawdust, mixed plastic waste, and ground tire rubber. This system will eliminate the need to purchase a liquid feedstock by allowing solid waste to be fed directly into the reactor.

Objectives

- Bring feedstock into a 300 psi environment
  - Sawdust
  - Mixed plastic waste (Grades #4-6)
  - Ground tire rubber
- Bring feedstock to at least 150*°C*
- Feed continuously
- Stand-alone system
- Limit required feedstock pre-processing

Methods

To accomplish our objective, we developed a novel design with **five key components**: a **pressurizing feed system**, a **twin screw extruder**, a **rotary pressure seal system**, a **motor drive system**, and a **custom gearbox**. Calculations and simulation were performed to ensure proper safety and sealing for all components, and special care was taken in manufacturing to ensure proper production quality.

Results and Conclusions

This project succesfully designed a stand alone system to move waste from atmospheric pressure into a 300 psi enviroment and heat to 150*°C*. Through engineering analyses, we succesfully verified the system can move feedstock at 5 kg/hr if the feedstock density exceeds 250 kilograms per meter cubed.

Additionally, this project demonstrated the feasibility of manufacturing advanced custom parts for a twin screw extruder and piston feeder system within a range of $600 of our $5,600 budget.

Acknowledgments

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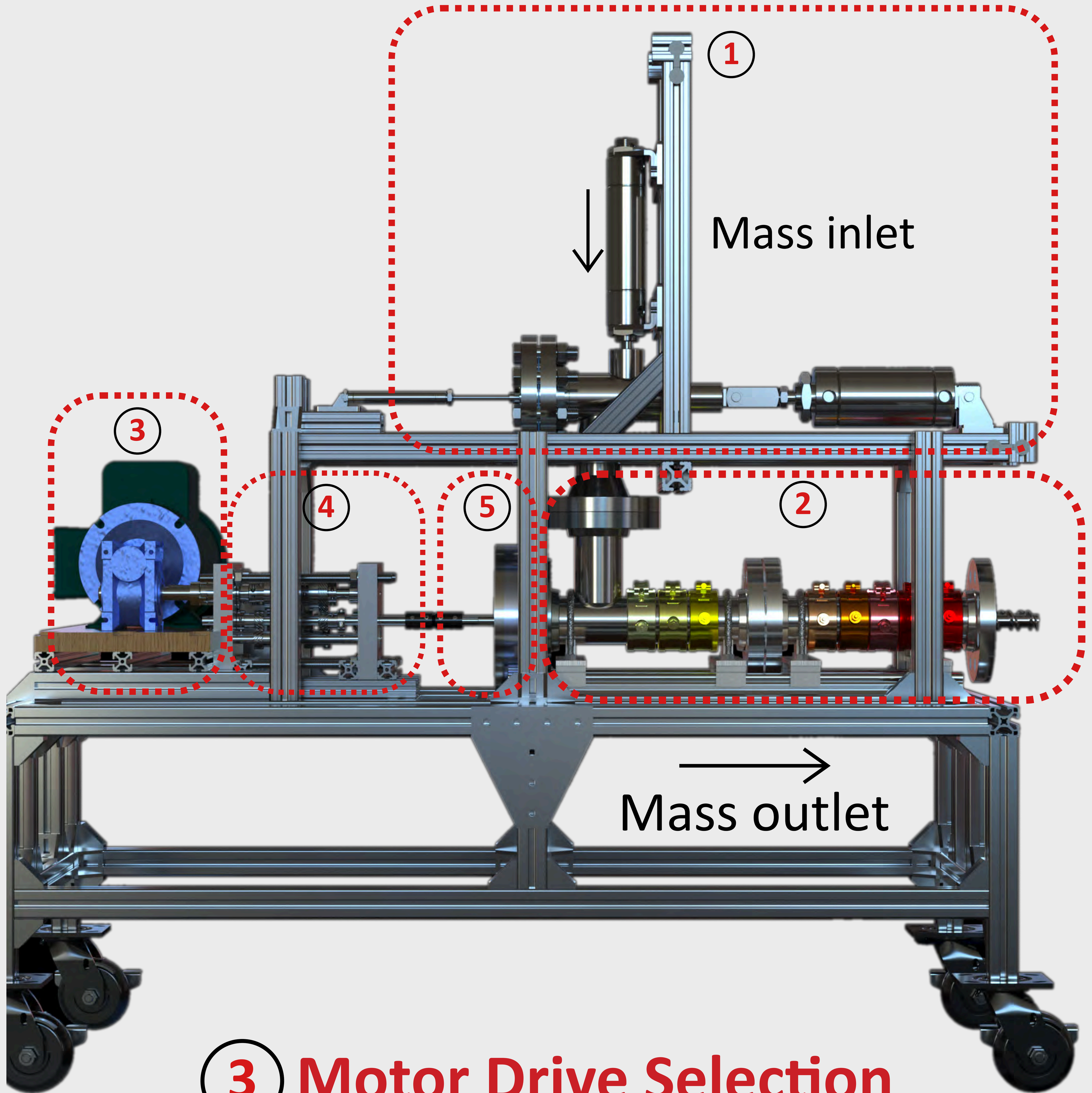
BRAUN MACHINE WORKS

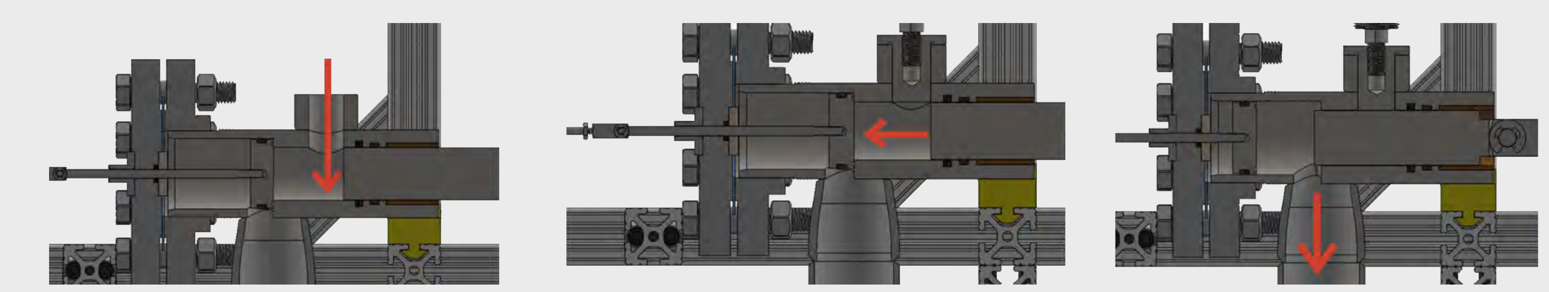


1 Piston Feeder Design

Requirements:
- Bring feedstock into 300 psi environment
- Prevent pressure backflow
- Feed at 5 kg/hr
- Feed into Stage 2

Features:
- Actuated using pneumatic cylinders
  - Only requires pressurized air
- Prevent backflow: alternating sealing
  - 2 rod seals, 2 O-ring face seals

Analysis:
- Thin walled pressure vessel analysis
  - Factor of Safety = 4
  - Min. wall thickness = 0.0297 in.
  - Designed value = 0.188 in.
- Actuator flow rate requirements
  - 1 second strokes = 10 second cycle
  - Max. air flow rate = 17.9 scfm
  - Operational flow rate = 3.51 scfm

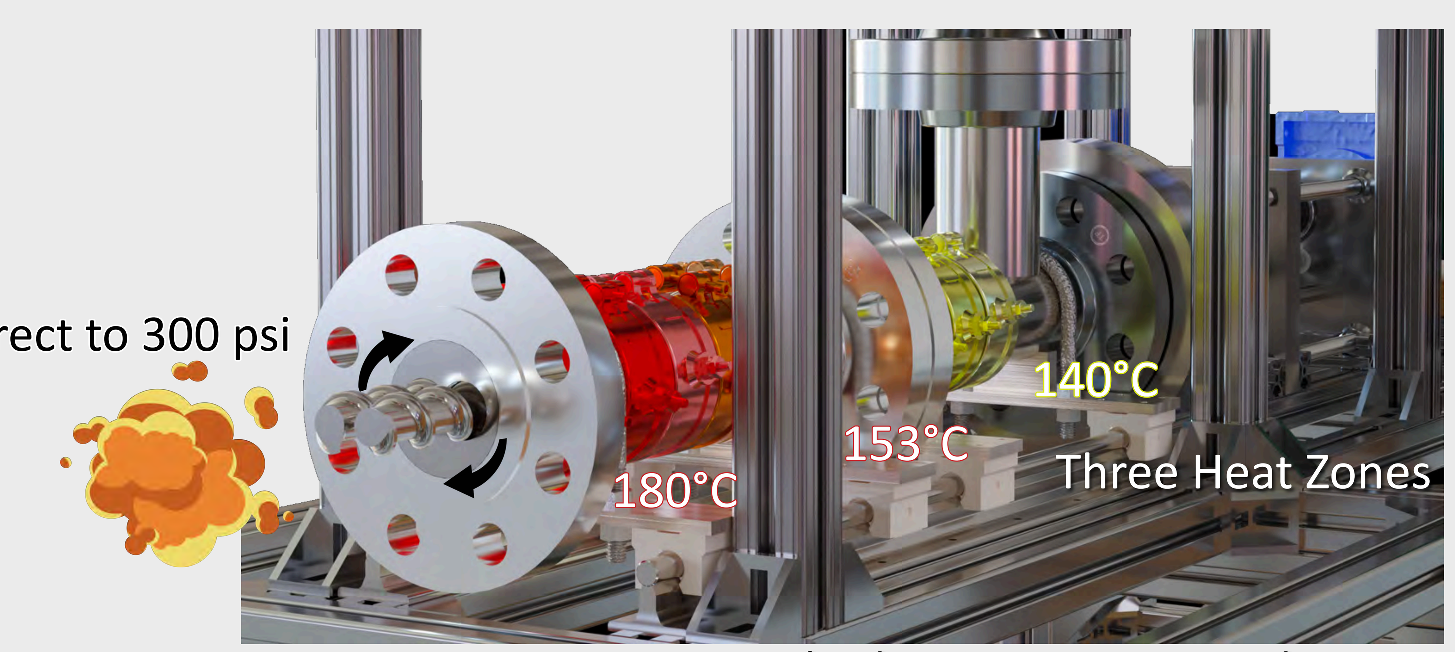


2 Twin Extruder Design

Requirements:
- *Maintain 300 psi pressure*
- *Bring feedstock to at least 150°C*
- Limit required feedstock pre-processing
- **Connect & convey feedstock to reactor**

Features:
- Co-rotating intermeshing twin screws
- Inter-changeable Barrel Sections
- Wear-resistant P20 Tool Steel Barrel

Analysis:
- Modeling Effective Feedstock Properties
  - Effective High Viscosity = 1,127 [Pa*s]
  - Effective Low Viscosity = 603 [Pa*s]
  - Effective Melt Temperature = 153 [°C]
- Modeling flow twin scew design
  - 19.9 kg/hr predicted output (MATLAB)
- Thermal Energy System Design
  - Heat Energy Required = 511.5 W
  - Barrel Expansion at 300°C = 4e-5mm/mm



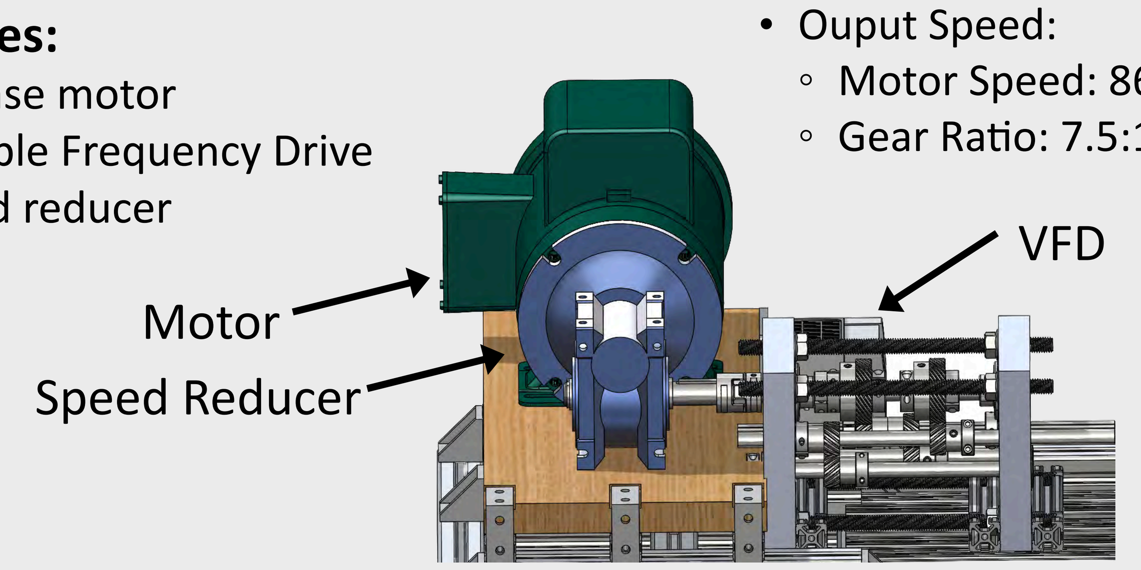
Co-Rotating Intermeshed Twin Screw Extruder

3 Motor Drive Selection

Requirements:
- Tourque demand of 11.25Nm per screw
- Screws must run between 50-240rpm

Features:
- 3-Phase motor
- Variable Frequency Drive
- Speed reducer

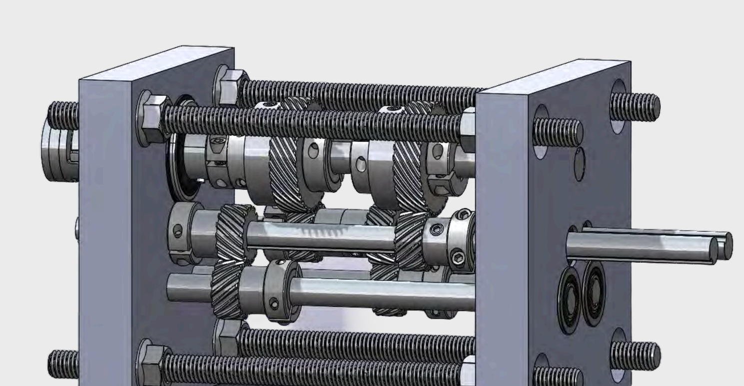
Analysis
- Power requirement
  - Max Output Torque: 11.54Nm
  - Factor of Safety: 2
- Ouput Speed:
  - Motor Speed: 860 RPM
  - Gear Ratio: 7.5:1



4 Co-Rotating Gearbox

Requirements:
- One input to two outputs
- Max torque for corotating twin-screw is 26.7 Nm per screw

Features:
- Helical gear configuration
  - 97% efficiency



5 Extruder Pressure Isolation

Requirements:
- Prevent screw shaft pressure leakge
- Allow power transmission to screws

Features:
- Stackable V-ring seals
- Custom machined plates