Enabling Entrained-Flow Gasification of Blends of Coal, Biomass and Plastics

DE-FE0032042

Logan Hughey and Kevin J. Whitty
The University of Utah

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Blended Fuel Gasification

Coal

Biomass

Plastic Waste

Blended feedstock for entrained-flow gasification

Dry feeding of biomass and plastic difficult at high temperature and pressure

Biomass very heterogenous and mixes poorly in water-based slurry

Plastic and biomass milling is very energy intensive

Solution: Prepare biomass and plastic as liquids
Technical Approach

Coal

- Grinding

Biomass

- Pyrolysis

Waste plastic

- Liquefaction

- Grinding

Pulverized coal

Pyrolytic bio-liquid

Torrefied biomass

Plastic oil

Plastic granules

Slurry
Technical Approach

- **High pressure, entrained-flow gasification of blended fuel**
  - EFG has proven track record
  - Should have good conversion, syngas quality
  - Can be used with existing coal gasification facilities
  - Integration with downstream synthesis is straightforward

- **Biomass and plastic fed as liquids**
  - Biomass as pyrolytic bio-liquid from Ensyn's process
  - Plastic as oil from Renewlogy process
Project Partners

- **University of Utah:**
  - Gasification R&D since 2001
  - Both lab-scale fundamentals and pilot-scale development

- **Eastman Chemical Co:**
  - Manufacturer of chemicals, plastics, advanced materials
  - Gasifying coal at Kingsport, TN facility since 1983

- **Ensyn Technologies**
  - Pyrolysis-based technology to turn biomass into liquid
  - Commercial process since 1980s

- **Renewlogy**
  - Salt Lake City-based company turning waste plastics into liquids
  - Commercial units approx 10 ton/day

- **Linde Inc**
  - Industrial Gas supplier
  - Has patented hot oxygen burner (HOB) technology
Technical Approach – Feedstocks

- **Biomass** – Biomass pyrolysis liquid (Ensyn)
  - Condensation of vapors from fast pyrolysis
  - 80-85% energy retention
  - Sand-based bed material (no catalysts)

- **Plastic Waste** – Plastic oil (Renewlogy)
  - Liquefaction via catalytic thermal depolymerization
  - Very low energy requirement
  - Can handle unclean plastics and challenging 4-7 types

- **Coal** (University of Utah)
  - Bituminous coal – Illinois number 6
  - Pulverized for ease of feeding
Project Objectives

- **Overall objective:** Demonstrate technical feasibility of gasifying blends of coal, biomass and mixed waste plastics in entrained-flow gasifier for production of H$_2$ with potential for net negative CO$_2$ emissions

- **Specific objectives:**
  1. Determine compositions of coal-biomass-plastic mixture that produce stable slurry suitable for pumping to high pressure
  2. Design and test novel burner to effectively atomize slurry in high pressure gasifier
  3. Acquire first-of-a-kind performance data for pressurized O$_2$-blown, entrained-flow gasification of slurried blends of coal, biomass and plastic waste
Project Structure – Tasks

1. Project management and planning

2. Preparation and characterization of mixed feedstock slurries (year 1)
   2.1 Procurement of feedstock materials
   2.2 Preparation of mixed feedstock slurries
   2.3 Physical and chemical characterization

3. Transport and atomization of mixed feedstock slurries (year 1)
   3.1 High pressure pumping studies
   3.2 Design and construction of HOB gasifier burner
   3.3 Characterization of burner atomization

4. Entrained-flow gasification of mixed feedstock slurries (year 2)
   4.1 Gasifier modeling and selection of operating conditions
   4.2 Baseline and parametric gasification testing
   4.3 Measurement of syngas composition and contaminants
   4.4 Evaluation of slag characteristics
Task 2 – Creation of Mixed Feedstock Slurries

- **Subtask 2.1** – Procurement of Feedstock Materials
- **Subtask 2.2** – Preparation of Mixed Feedstock Slurries
  - 12 baseline slurries
  - Qualitative assessment complete
  - Favorable slurries Identified
- **Subtask 2.3** – Physical and Chemical Characterization
  - Separation tests, proximate analysis, viscosity
Task 2 – Mixed Feedstock Slurries

- Mixture requirements per FOA (HHV basis):
  - Biomass: 25, 40, 60%
  - Remainder: 25, 50, 75, 100% coal

- Result is 12 mixtures

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<th>Heating value basis</th>
<th>Mass basis (wt%)</th>
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Best properties: less than 45 wt% coal, less than 20 wt% plastic oil
## Task 2 – Mixed Feedstock Slurry Properties

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Task 2 – Slurry Properties

**Slurry 10**
- 25 wt% coal  |  70 wt% bio-liquid  |  5 wt% plastic oil

Proximate analysis by TGA

Rheology
Task 3 – Slurry Pumping Studies

- Subtask 3.1 – High Pressure Pumping Studies
  - Ensure reliability of slurry feed
  - Low- and high-pressure studies using progressive cavity pump
  - Identify minimum usable channel diameter

Minimum channel diameter impacts HOB design

Moyno progressive cavity pump

Plugging occurs if channel diameter is too small
Subtask 3.2 – Design and Construction of HOB

HOB = Hot Oxygen Burner

- Design based on other hot oxygen burners for liquid fuels
- Adaptations include adjustments for increased pressure, lower firing rate and using particulate-containing slurry
- HOB design will also allow for natural gas feed, simplifying operation
  - Enables use as a warmup burner
  - Allows system to start gasification mode on NG and line up analytical systems, enabling focus during liquid feeding
- Design work nearly complete
  - Long lead materials have been ordered
  - Confirming University of Utah reactor configuration works
Subtask 4.1 – Gasifier modeling and selection of operating conditions

- Modeling performed using FactSage™ thermodynamic modeling software
- Used compositions of coal, biomass, plastic to determine compositions of mixtures
- Assume gasification with 35% of stoichiometric O₂
- Calculate flame temperature and equilibrium gas composition

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<th>H₂ (%)</th>
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Task 4 – Entrained Flow Gasification

- Testing planned for year 2 of project
- System modifications complete
- System shakedown in progress

U. Utah pressurized, oxygen-blown entrained-flow gasifier. Target conditions: 300 psi, 1 ton/day (~300 kW_{th}) feed rate.
Plans for Coming Year

- Continue evaluating candidate slurries
- Construct, test, and install hot oxygen burner
- Evaluate gasification of mixed feedstock slurries
  - Syngas composition
  - Carbon conversion
  - Slag properties

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Acknowledgements

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- Project partners
  - Eastman Chemical Company
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  - Ensyn Technologies
  - Renewlogy Technologies

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