Design and Operation of a Multi-Bed Catalytic Micro-Reactor for the Study of Co-Processing of Bio-oils with VGO

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Background

- As refineries transition to renewable feedstocks, there is a need for process de-risking to minimize financial loss
- Online mass spectrometry will give real time insight into product formation and process behavior
- We have designed and built a multi-bed catalytic reactor for higher throughput screening of catalyst and process conditions to provide data for development of predictive tools that will give insight into product formation for refineries transitioning to renewable feedstocks

Figure 1: Multi-bed catalytic micro reactor with no heat tape or insulation

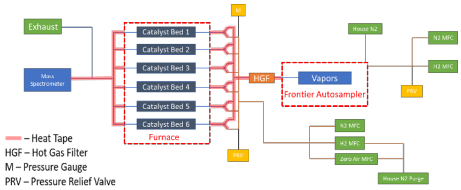

Figure 2: Schematic of multi-bed catalytic micro reactor

Overview

- Six reactor beds which can be reduced or oxidized simultaneously then assessed in sequence
- Micro-Pyrolyzer and Auto-Shot Sampler increase throughput by an estimated 10x over other microscale reactor configurations
- Molecular beam mass spectrometer allows for online analysis of upgraded product
- Carried out 104 unique experiments (consisting of over 900 individual runs) since commissioning

Design

- Created to increase throughput of microscale analysis of feedstocks and catalysts for vapor phase upgrading
- Reactor beds designed to be easily removable to facilitate catalyst changes
- Hand valves allow for easy transitions between different catalyst beds
- Multiple heating zones create accurate and uniform thermal regulation
- 80/20 framework used to ease movement of reactor system

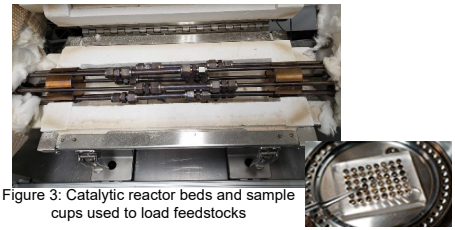

Figure 3: Catalytic reactor beds and sample cups used to load feedstocks

Unique Capabilities

- Autosampler can accommodate for up to 48 samples per experimental set
- Capable of handling both liquid and solid feedstocks
- Mass spectrometry gives insight into real time product characterization
- Auto-Sampler streamlines procedures and allows for fine-tuning of process conditions
- Configuration allows for catalyst regeneration of all six beds at once

Current Experiments

- Work focuses on characterization of feedstocks relevant to co-processing of renewable feedstocks with vacuum gas oil
- Feedstocks include: Lignocellulosic-derived pyrolysis and catalytic fast pyrolysis oils, Model Compounds, VGO, Bio-Oils, Fats Oils and Greases, Fischer-Tropsch Waxes, Renewable Diesel
- Mass spectral data is used to train a neural network that will be used to predict product spectra for refineries of the future

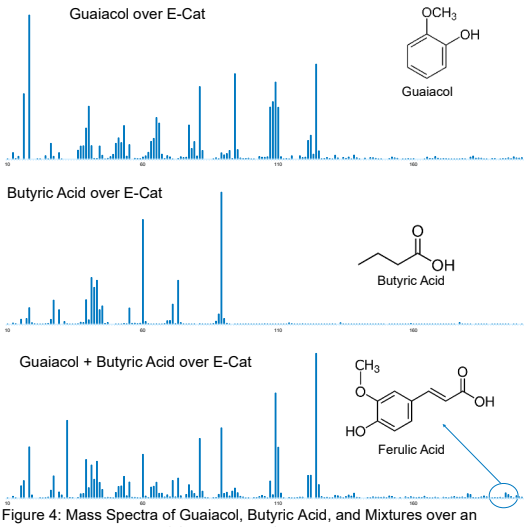

Figure 4: Mass Spectra of Guaiacol, Butyric Acid, and Mixtures over an FCC Equilibrium Catalyst

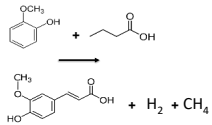

Figure 5: Reaction mechanism for conversion of Guaiacol and Butyric Acid to Ferulic Acid

Future Work

- Generating large sets of mass spectral data for vapor phase upgrading
- Long-term catalyst deactivation studies
- Effects of catalyst bed temperature on product formation

Acknowledgments

- We would like to thank Johnson Matthey and Equilibrium Catalyst Corporation for providing the catalysts for this work
- We would also like to thank the NREL DCR and TCPDU operation teams for their insight and assistance in reactor design and operation

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This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by DOE Bioenergy Technologies Office (BETO) and Systems Development and Integration Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

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4/19/2022-4/21/2022
NREL/PO-5100-82626