Co-processing of Biofuel oil (BFO) with Vacuum Gas Oil (VGO) to Transport Fuel in FCC Reactor

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Introduction

• The global energy demand

Global fuel energy demand scenarios
Reference: OGUK economic report 2020

Change in consumption by sector and fuel, 2019
Reference: OGUK economic report 2020

UK energy consumption by sector, 2019
Reference: OGUK economic report 2020

Change in consumption in transport by travel mode and fuel, 2019
Reference: OGUK economic report 2020
A simplified refinery processes

- FCC is the “Heart” of refinery
- Catalytically cracked VGO into transportation fuels (e.g. gasoline, diesel, jet fuel)
- Processing capacity of over 14.7 million barrels per day
- About 45% of all gasoline comes from FCC (Reza, 2012)
Fluid catalytic cracking unit (FCC)

(Vogt & Weckhuysen, 2015)
Conversion routes

Biomass feed

Catalytic fast pyrolysis → 2 → Bio-oil

Extraction/Esterification → 3 → BFO

Fast pyrolysis → 1 → Bio-diesel

FCC Unit

Hydrotreating

Transportation fuels: gasoline, diesel etc.
Aims and objectives

- The aim of this research is to investigate the level of bio-oil that could be incorporated into fluid catalytic cracking (FCC) unit by co-processing VGO with BFO.

- To evaluate the potential of co-processing BFO with VGO in FCC using laboratory batch microactivity (MAT) reactor for the production of biofuels. Blending ratios of 10, 20 and 50 and catalyst to oil ratio ranging from 2.5 to 5.5.
## Properties of VGO and BFO

<table>
<thead>
<tr>
<th>Elemental analysis (wt.%)</th>
<th>VGO</th>
<th>BFO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>86.6</td>
<td>76.3</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>12.2</td>
<td>11.9</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>1.3</td>
<td>2.4</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.24</td>
<td>0.18</td>
</tr>
<tr>
<td>Oxygen</td>
<td>0</td>
<td>9.2</td>
</tr>
<tr>
<td>HHV (MJ/kg)</td>
<td>43.01</td>
<td>40.3</td>
</tr>
<tr>
<td>H/C</td>
<td>1.7</td>
<td>1.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Simulated distillation (°C), D2887</th>
<th>VGO</th>
<th>BFO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial boiling point</td>
<td>204</td>
<td>331</td>
</tr>
<tr>
<td>10%</td>
<td>302</td>
<td>369</td>
</tr>
<tr>
<td>25%</td>
<td>365</td>
<td>423</td>
</tr>
<tr>
<td>50%</td>
<td>426</td>
<td>522</td>
</tr>
<tr>
<td>70%</td>
<td>462</td>
<td>570</td>
</tr>
<tr>
<td>90%</td>
<td>519</td>
<td>600</td>
</tr>
<tr>
<td>Final boiling point</td>
<td>600</td>
<td>700</td>
</tr>
</tbody>
</table>
GCMS analysis of VGO and BFO

18uME – octadecenoic acid methyl ester
18ME – octadecanoic acid methyl ester
18AM – octadecanamide

BFO
## Microactivity (MAT) reactor feedstocks

<table>
<thead>
<tr>
<th>Feed</th>
<th>Sequence</th>
<th>Composition</th>
<th>catalyst to oil ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>V1</td>
<td>VGO (100 wt%)</td>
<td>3.04</td>
</tr>
<tr>
<td>2</td>
<td>V2</td>
<td>VGO (100 wt%)</td>
<td>4.7</td>
</tr>
<tr>
<td>3</td>
<td>V3</td>
<td>VGO (100 wt%)</td>
<td>5.6</td>
</tr>
<tr>
<td>4</td>
<td>VB1</td>
<td>VGO + BFO (10 wt%)</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>VB2</td>
<td>VGO + BFO (10 wt%)</td>
<td>4.1</td>
</tr>
<tr>
<td>6</td>
<td>VB3</td>
<td>VGO + BFO (10 wt%)</td>
<td>5.1</td>
</tr>
<tr>
<td>7</td>
<td>VBA</td>
<td>VGO + BFO (20 wt%)</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>VBB</td>
<td>VGO + BFO (20 wt%)</td>
<td>4.1</td>
</tr>
<tr>
<td>9</td>
<td>VBC</td>
<td>VGO + BFO (20 wt%)</td>
<td>5.4</td>
</tr>
<tr>
<td>10</td>
<td>B1</td>
<td>BFO (100 wt%)</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>B2</td>
<td>BFO (100 wt%)</td>
<td>4.2</td>
</tr>
<tr>
<td>12</td>
<td>B3</td>
<td>BFO (100 wt%)</td>
<td>5.7</td>
</tr>
<tr>
<td>13</td>
<td>GB</td>
<td>VGO + BFO (50%)</td>
<td>2.6</td>
</tr>
</tbody>
</table>

Total of 39 successful runs
Experimental set up

1. Reactor
2. Tube furnace
3. Nitrogen gas
4. Catalyst bed
5. Glass wool
6. Oil receiver
7. Cold bath
8. Gas bag
9. Syringe pump
Product yields calculation

- Dry gases (C₁ – C₂)
- Liquefied petroleum gas (LPG: C₃ – C₄)
- Gasoline (C₅ – C₁₂)
- Light cycle oil (LCO: C₁₃ – C₂₀)
- Heavy cycle oil (HCO)
- Coke

- Yield of $i$th product $= \frac{\text{mass of } i\text{th product}}{\text{total mass of oil feed}}$

- Mass balance (recovery) $= \frac{\sum \text{all products}}{\text{total mass of oil feed}} \times 100\% = \frac{\text{output}}{\text{input}} \times 100\%$

- Conversion $= \text{Yield of (Gasoline + LPG + Dry gases + Coke)}$
Products recovery / mass balance

Graphs showing the yield and mass balance for different categories such as gas, coke, and liquid hydrocarbons. The graphs display the percentage yield and mass balance for various components labeled as V1, V2, V3, V81, V82, V83, V8A, V8B, V8C, B1, B2, and B3.
Conversion vs catalyst to oil ratio
Products conversion

Graphs showing the conversion of products with varying catalyst/oil ratios for different blends:
- Gasoline (wt%)
- LPG (wt%)
- Coke (wt%)
- Dry Gas (wt%)

Key:
- VGO 100%
- VGO 90% + BFO 10%
- VGO 80% + BFO 20%
- BFO 100%
- VGO 50% + BFO 50%
- VGO4
Products yields
Products yields
Next

- Analysis of chemical compounds in the liquid products
- Coke properties
Thank you for listening

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