Catalytic Dewaxing

Catalytic dewaxing is a particular hydrocracking process used to improve cold flow properties of middle distillates and lubricants by cracking normal paraffins. Dewaxing can be achieved by isomerization, as carried out by Chevron’s isodewaxing process. Isoparaffins have lower melting points than normal paraffins. The properties targeted for improvement are pour point and viscosity of middle distillates and lubricants, the cloud point of diesel fuel, and the freeze point of jet fuel. Due to their high melting points, long-chain normal paraffins have the most detrimental effect on low temperature properties of middle distillates and lube oils. By reducing the amount or chain length of normal and minimally branched paraffins in these fuels and lubricants, their cold flow properties are improved. This can be accomplished by using a catalytic dewaxing process. Such a process can also be used to improve the flow properties of gas oils. A single-stage, once through hydrocracking process can be used for catalytic dewaxing, with or without hydrotreating, depending on the sulphur and nitrogen content of the feedstock. The catalytic process is carried out as a trickle bed reactor over a bifunctional zeolite catalyst under hydrogen flow. A non-noble metal (e.g. nickel) supported on a medium-pore zeolite, such as ZSM-5 can be used. The medium-pore zeolite ZSM-5 appears to be particularly suitable to obtain a high selectivity.

Hydrocracking Correlations

Yield Correlations

The yield correlations in conventional hydrocracking depend on feed properties, hydrogen severity and mode of operation. There are three modes of operation: maximum gasoline mode, maximum ATK mode (jet fuel) and maximum diesel fuel. In all these modes, gasoline yield is used to correlate other yields. Using mild hydrocracking (low severity) will add a fourth mode of operation, maximum low sulphur fuel oil (LSFO). The hydrogen severity ranges between (1.5 – 4) wt% of feed. In mild hydrocracking it can be assumed as 1.5 wt% and in conventional hydrocracking as 3.0 wt%. In high severity (high aromatic feeds) it can be assumed as 4.0 wt% of feed. ATK mode is frequently used because of the high demand for aviation fuels.

Maximum ATK Correlations

The ATK mode yield correlations are given here as an example. These correlations are developed from plant data. The following is the calculation procedure for ATK yields:
- Hydrocracking severity $H$ where
  \[
  H \text{ wt}\% = \frac{\text{lb Hydrogen}}{\text{lb of feed}} \times 100
  \]
  For maximum ATK, assume $H = 3$ wt\%
  In this case $V_H = \frac{\text{thousands of ft}^3 \text{ hydrogen}}{\text{bbl feed}}$
  And is related to hydrocracking severity as
  \[
  V_H = 0.6621 \times H \times SG
  \]
- Calculate liquid volume\% (LV\%) of gasoline
  \[
  \text{Gasoline LV}\% = -0.03734 \text{ API}_f^2 + 1.57575 \text{ API}_f + 0.014923 K
  \]
  \[
  -1.36473 V_H - 0.16324 V_H/K
  \]
  Where $K = (T_B)^{1/3}/SG$
- Butanes (iC$_4$ and nC$_4$)
  \[
  C_4 \text{ LV}\% = 0.020359 (\text{LV}\% \text{ Gasoline})^2 + 0.04888 (\text{LV}\% \text{ Gasoline}) + 0.108964 \text{API}_f
  \]
- Heavy naphtha (HN) (180–380 °F)
  \[
  \text{HN LV}\% = -0.10322 (\text{LV}\% \text{ Gasoline})^2 + 2.981215 (\text{LV}\% \text{ Gasoline}) - 0.07898 \text{API}_f
  \]
- ATK
  Calculated by mass difference between feed and products
- The following equation is used to convert LV\% to wt\% of hydrocarbon products
  \[
  \text{Product wt}\% = 0.8672 \times \text{Product LV}\% - 0.9969
  \]

Example:
A feed of VGO of 37,500 BPCD is hydrocracked to maximize the ATK production. The API of the feed is 20 and the mean average boiling point $T_B = 575$ F. Make material balance around this hydrocraker.

Solution:
From feed API of 20 the SG is 0.934
Assume $H = 3$ wt\% then
\[
V_H = 0.6621 \times 3 \times 0.934 = 1.855 \text{ ft}^3/\text{bbl}
\]
\[
K = (575+460)^{1/3} / (0.934) = 10.83
\]
Gasoline \[
\text{LV}\% = -0.03734(20)^2 + 1.57575 \times 20 + 0.014923 \times 10.83
- 1.36473 \times 1.855 - 0.16324 (1.855/10.83) = 14.18
\]
Gasoline \[
\text{wt}\% = 0.8672 \times 14.18 - 0.9969 = 11.30
\]
\[ C_4 \text{ LV\%} = 0.020359 \times (14.18)^2 + 0.04888 \times (14.18) + 0.108964 \times 20 = 6.96 \]

\[ C_4 \text{ wt\%} = 0.8672 \times 6.96 - 0.9969 = 5.04 \]

\[ \text{HN LV\%} = -0.10322 \times (14.18)^2 + 2.981215 \times (14.18) - 0.07898 \times 20 = 19.94 \]

\[ \text{HN wt\%} = 0.8672 \times 19.94 - 0.9969 = 16.29 \]

\[ \text{ATK wt\%} = 100 + 3 - 11.30 - 5.04 - 16.29 = 70.37 \]

Summary of material balance:

<table>
<thead>
<tr>
<th>Feed</th>
<th>VGO</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hydrogen</td>
<td>3.00</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>103.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Products</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( C_4 )</td>
<td>5.04</td>
</tr>
<tr>
<td>Gasoline (( C_{5-180 \degree F} ))</td>
<td>11.3</td>
</tr>
<tr>
<td>HN (( 180 - 400 \degree F ))</td>
<td>16.29</td>
</tr>
<tr>
<td>ATK (+400 \degree F)</td>
<td>70.37</td>
</tr>
<tr>
<td>Total</td>
<td>103.0</td>
</tr>
</tbody>
</table>