cracking conversions

Bent Sarup, Haldor Topsøe A/S, Denmark, and Kerstin Efraimsson, Preemraff Gothenburg, Sweden, demonstrate maximising middle distillate yield from heavy gasoil using the company's mild hydrocracking technology and catalysts.

Investments in clean fuel production facilities have been prominent in the investment portfolio of many refineries within the last decade and continue to be so. Legislation has been the main driver for this, assisted in many cases by tax incentives. At the same time, refiners are pressed to demonstrate competitive rates of return on their total capital expenditure. This puts new investments under pressure while demanding maximum cash flows from existing facilities. Developments in catalyst technology and high performance reactor internals combined with design models and engineering capabilities provide new opportunities for refiners to improve the performance of their businesses.

This article will focus on such new opportunities for the conversion of heavy gas oil to middle distillate fuels and illustrate this with a recent revamp example.

Background

The European market directive 98/70/EC with the amendment directive 2003/17/EC has set the overall standard for petrol and diesel fuel quality within the European Union. Member states have in some cases stricter requirements in place. Table 1 provides an overview of these specifications. Within Europe, Sweden has taken the lead in strict diesel specifications, such as those for MK-1 diesel. However, in other Scandinavian countries, as well as in the UK and Germany, the move towards cleaner diesel fuels has been faster than the common European level. Furthermore, tax incentives are in place (e.g. in Sweden and Germany) to stimulate both producers and consumers to move towards these stricter fuel specifications.

In addition, heating and marine gas oil maximum sulfur specification will be reduced from 0.2 to 0.1 wt%. from 1st January 2008 (EU directive 99/32/EC). Directive 99/32 is currently set to be amended to include stricter sulfur limits for marine diesel and marine heavy fuels.

For many refiners, the reduction in diesel endpoint has meant that distillate material has to be moved from higher margin diesel products to lower margin fuel or heating oil products. Revamps that increase the yield of high quality diesel blending products from heavy gas oil are therefore of considerable value. Hydrocracking of HGO at the moderate pressures in existing hydrotreaters does require high activity hydrocracking catalyst system, while retaining a high selectivity to middle distillates.

A combination of the high activity pretreatment catalyst TK-565 and the maximum middle distillate mild hydrocracking catalyst (TK-961) give rise to new opportunities to maximise high quality diesel yield in medium pressure plants. TK-565 is a NiMo catalyst with an exceptionally high HDN activity. This superior activity can be used to either extend cycle length or produce products with lower nitrogen content, with a benefit for the hydrocracking catalyst.

TK-961 is a novel amorphous NiW hydrocracking catalyst that, compared with traditional amorphous hydrocracking catalysts, has shown better middle distillate yields and improved product properties, such as lower aromatic content, higher cetane index in diesel and higher smoke point in jet. This improved hydrocracking performance is based on a unique catalyst formulation to increase hydrocracking activity while retaining product selectivity.

Case study

The Preemraff Gothenburg refinery has long been manufacturing high quality transportation fuels in line with the stringent Swedish specifications.

In 1996 the Preemraff refinery was upgraded with a dearomatisation unit treating LGO and a parallel 60 bar CFI unit to upgrade HGO. The CFI unit was built to desulfurise heavy gasoil while improving its cold flow properties and improve the boiling point range of the gas oil material by mild hydrocracking. However, since startup, the severity of the unit operation has been limited by colour formed in the reactor at high temperatures, as well as too low activity at the prevailing hydrogen partial pressure. A large part of the gasoil produced in the CFI unit was originally to be blended in the diesel pool, but the colour limitations and changes in the diesel oil specifications have decreased the amount useful for diesel production. This is mostly due to stricter requirements for the heavy end of the diesel. Instead, the CFI product is sold as a lower value gasoil component.

Table 1. Diesel property requirements

	EU (BS EN 590)		UK ULSD MK-1		Swedish	
	Min	Max	Min	Max	Min	Max
Density, kg/m^3	-	845	820	835	810	820
IBP, D86	-	-	-	-	180	-
Distillation						
95% v/v recov., D86	-	360	-	345		285
Sulfur, ppm wt*	-	50		50	-	10
Cetane number	51	-	51	-	-	-
Cetane index		-	46	-	50	-
Aromatics total, LV%	-	-	-	-	-	20
Polyaromatics, %wt	-	11	-	11	-	6

** 10 ppm limit should be marketed from 1st January 2005, to be mandatory maximum limit from 1st January 2009*

Scoping study work with Topsøe was initiated with engineering and pilot plant efforts. The objective was to identify the optimum revamp solution to maximise conversion of HGO to middle distillated at increased cutpoint between HGO and resid, while also keeping naphtha production at a low level. Furthermore, it was desirable to identify modifications to the fractionation system that, at minimum investment levels, would enable separation of the product into high quality diesel blending streams and a heavy part that could be used as a heating or fuel oil component. At the same time, the fractionation system should be adequately flexible to provide optimum blendstocks for both Swedish MK-1 operation modes and operation modes for the new EU specifications.

The work took place in close collaboration with Preemraff refinery process engineers to make maximum use of accumulated operating experience. The design feed was a straight run HGO from North Sea crudes. Properties are given in Table 2.

Table 2. Feed properties

Feed property	
Specific gravity	0.878
Sulfur, % w/w	0.25
Cloud point, ˚C	28
95% D1160, ˚C	453 - 458

Table 3. Diesel product properties

Property	Value
Sulfur, ppm wt	< 1
95% distillation point (D86), ˚C	340
Density, kg/m^3	858
Cetane index, D976	42
Cloud point, ˚C	-15
Colour, D-1500	0.5
Polyaromatics, % wt	< 9

Table 4. Properties of hydroprocessed heavy product

Property	Value
Sulfur, ppm wt	5
95% distillation point (D86), ˚C	465
Density, kg/m^3	858
Viscocity at 40 ˚C, mm^2/s	15

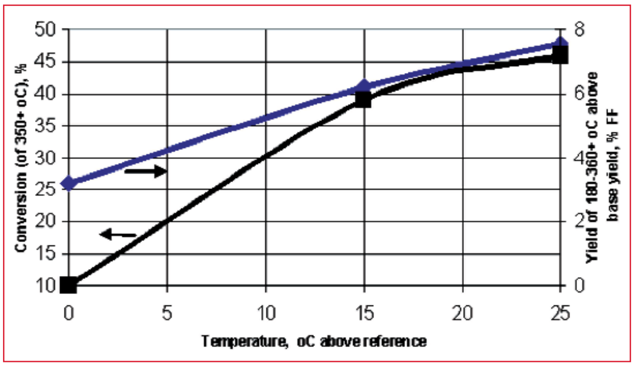

Figure 1. Conversion and yield pilot plant results.

Scoping study results

Some pilot results are shown in Figure 1. The conversion of the 350 ˚C material ranged from 25 - 48 wt% over the temperature range studied. Notable from the results is the relatively flat yield curve at conversion levels above 40 wt%, which was selected as the operating region. Pilot plant results also confirmed a good margin to the maximum allowable naphtha production.

Sulfur content of the middle distillates in the conversion range above 40 wt% was in the range of 2 - 5 ppm wt. Polyaromatics were in the same conversion range of 5 - 7 wt%. Middle distillate colour was in all cases below 0.5 (D1500).

Based on pilot plant results and check rating of existing equipment, it was concluded that the volumetric design capacity of the unit could be increased by 27% without the need to add catalyst volume. In fact, the only required equipment change in the reactor loop was new internals in the multibed reactor. Topsøe's VLT high performance vapour-liquid distributors and new quench arrangements ensured efficient quench gas mixing.

To control the endpoint of the diesel blending products, additional fractionation facilities were added to the unit, as outlined in Figure 2.

The fractionation system produces an overhead low endpoint light distillate stream for blending of low endpoint diesel fuels, as well as a side diesel blending stream. The fractionation system was designed with maximum flexibility in mind, allowing withdrawal of the described streams separately, or feeding any of the streams to the parallel HDA unit.

Design conditions for the fractionation system were selected so that a reboiler was not required. Heat input for the column was delivered by the stripper bottoms stream and supplemented with hot oil heat delivered through a new, low duty trim preheater. In addition to the overhead system for the new fractionator, the new revamp equipment included three product pumps and a light product air cooler.

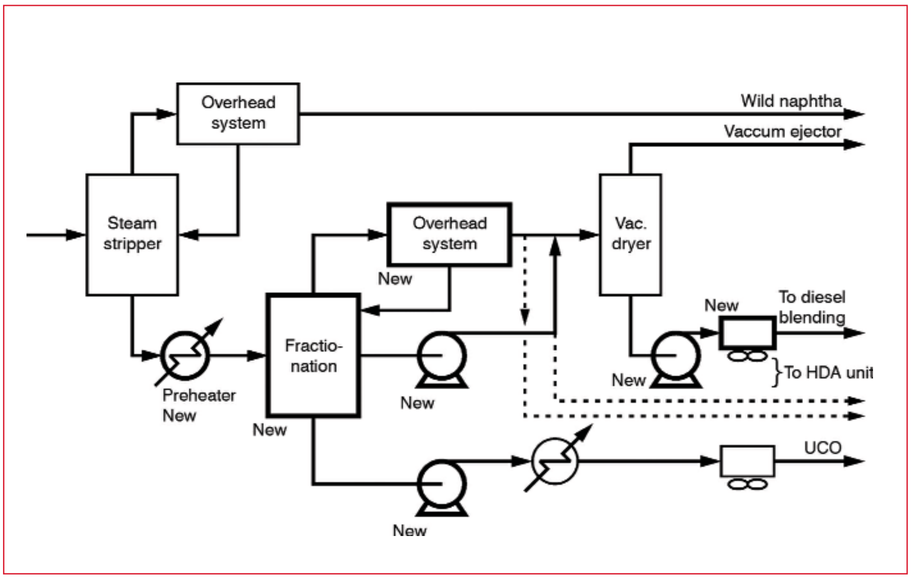

Figure 2. Revamped fractionation section.

In summary, the investment cost for the revamp was kept at a low level of € 1250/bpd, resulting in a payback time of 25 years, particularly as no modification of reactor loop requipment was required. The refinery gained a significant increase in capacity and conversion, while the modifications in the fractionation system added wide flexibility to produce blend streams to match current diesel pool requirements. The advantages of this flexibility include the ability to minimise the amount of kero that might be added to the diesel for adjustment of cold flow properties.

Unit performance

The Topsøe MHC unit was started up

in July 2003 under Topsøe supervision without major difficulties. Topsøe also supervised a test run conducted in August 2003. Unit performance was as expected on all performance values and in line with pilot plant results. Properties of the combined top product and side draw diesel blend stock are given in Table 3.

Sulfur content is below 1 ppm wt (plant measurements validated at Topsøe laboratories), and the cloud point is also at a very low level. The good margin on product properties gives flexibility in optimising the operation of the MHC plant for various crudes, seasonal requirements, etc., such as balancing feed EP, reactor operation and 95% point of diesel withdrawn from the MHC unit with the available diesel blend stocks.

The bottoms product from the fractionator was withdrawn with typical properties, as shown in Table 4.

The hydroprocessed heavy product makes an excellent blending stock for low sulfur fuel or heating oils, including the new grades of lower sulfur heating and marine fuels oils. The desulfurised HGO can be used to upgrade the value of lower quality heavy oils.

The revamped plant has now been in operation for almost two years. According to the original schedule, the catalysts should be changed out this summer. However, both the pretreating and the hydrocracking catalysts have shown such limited deactivation that Preemraff has decided to continue the present run until Spring 2007 by accepting an increased sulfur content in the product towards EOR (Figure 3).

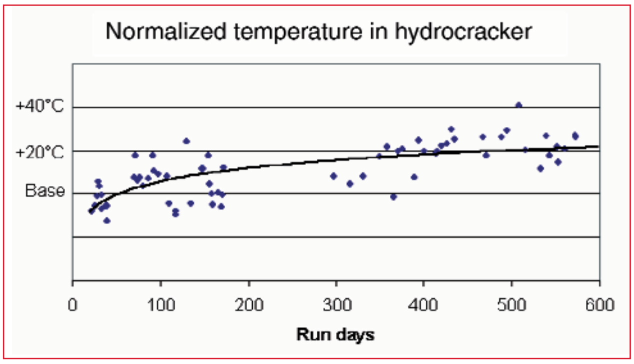

Figure 3. The installed Topsøe catalyst charge has shown an exceptionally high stability with very low deactivation rate, enabling Preemraff to extend the first cycle length beyond the initial expectations.

Conclusion

Topsøe's maximum middle distillate mild hydrocracking catalyst, TK-961, opens new possibilities to increase conversion of heavy gas oil into valuable middle distillates due to its high hydrogenation activity and the high selectivity to middle distillates. Such advances in catalyst and reactor internals technologies, along with reliable design models, are critical elements creating solutions for optimal capital spending.

Topsøe has been providing such innovative solutions in clean fuels production to the refining industry from the onset of the industry trend towards cleaner fuels. These solutions arise from common client-Topsøe teams bringing together technology and catalyst capabilities as well as refinery options, constraints and experiences.

A revamp of the CFI unit at Preemraff's Göteborg refinery to a Topsøe MHC unit has illustrated how this approach can help the refiner to achieve a high yield of high quality diesel blending stock at a low investment level within a short payback time.

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