Solving hydrotreating fouling problems

Upgraded antifoulant technology is helping refiners to overcome the increased hydrotreater fouling issues that result from more stringent fuel sulphur limits

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Lowering sulphur levels in finished fuels has been commonplace going back to the 1990s, in an effort to reduce greenhouse gas emissions and improve air quality. The European Union (EU) as far back as 1993 started regulating sulphur content in diesel fuels to reach 50 ppm by 1999 in some countries. By 2005, Euro IV standards were applied across the EU, and then in 2009 Euro V reduced the limit further to just 10 ppm. In 2014, Euro VI was in place, keeping 'sulphur-free' diesel and gasoline fuels (≤10ppm) mandatory.[1] China has followed the EU pathway for vehicle emissions standards, with China V standards analogous to Euro V and China VI heavy-duty emissions standards as stringent as Euro VI.[2]

Refineries have always adapted, typically through the introduction of new hydroprocessing technology. A great example of this occurred in 2006 when the US Environmental Protection Agency (EPA) set a new standard for diesel, lowering the sulphur limit from 500 ppm to the new ultra low sulphur diesel (ULSD) specification of 15 ppm, and diesel quality practically flipped overnight.[3] However, recently announced regulation changes concerning the sulphur level in marine fuels pose a new and significant challenge for the industry.

The International Maritime Organisation (IMO) set a new limit for sulphur in marine fuels to take effect in 2020.[4] This global cap of 0.5% sulphur (down from the current 3.5% sulphur) is challenging for a number of reasons, not all of which will be addressed in this article, but the question remains: "How will the refining market react to meet this target?" There is not sufficient hydroprocessing capacity to treat all bunker fuels to reach the IMO cap. It is also unlikely that the extra capacity will be built in time, nor is it likely that all shipping will upgrade their scrubbers to deal with increased sulphur particulate removal. One method is to 'dilute the pool' of high sulphur fuel oils (HSFO) with high quality (high value) low sulphur distillates or fuel oils (LSFO). Shell estimates a total of 3 million b/d of HSFO that needs to switch to the 0.5% sulphur cap by blending with LSFO streams.[5]

Additional fuel quality improvements followed, with the Tier 3 regulations on gasoline lowering sulphur to 10 ppm from 1 January 2017.[6] Refiners and importers must continue to sample, test, and report the sulphur content of each batch of gasoline which they produce or import. Regulations become more stringent globally, forcing refineries to run their assets under more severe conditions to meet these new vehicle emission and environmental standards. With higher conversion rates increasing unit 'stress', the industry will likely experience more widespread fouling issues. It is not always economically viable simply to run low sulphur crudes, so the processing challenges on hydrotreaters will likely increase.

Nalco Champion invests significantly in R&D and has leveraged more than 50 years of dedicated research and experience in fouling solutions and services to address these challenges globally. This article will share two recent case studies that detail the positive impact of new antifoulant innovations designed to help refineries address their fouling concerns, lower maintenance and energy costs, and maintain unit availability targets.

Case study 1

A major US refinery based on the East Coast was experiencing a higher than acceptable rate of fouling in the feed/effluent (F/E) exchangers to the naphtha hydrotreater (NHT). The refinery was averaging between 12-18 months of run length before the NHT required a unit shutdown for cleaning.

The hydrotreater processed a mixture of straight-run naphtha along with purchased coker naphtha. The combined feed is pumped to the tube side of the exchangers. There are four exchanger bundles in series, with two exchangers in each bundle. The refinery's goal was to restore the typical turnaround cycle between cleanings.

Solution

Mostly in response to the Tier 3 regulation changes, Nalco Champion had only recently commercialised new antifoulant chemistries to address these fouling challenges. In-house dynamic lab simulation testing showed these offerings performed better than the previous generation chemistry. Consequently, a field trial was developed to confirm the performance.

Results

Nalco Champion Monitor software is an advanced heat transfer modelling program that analyses fouling trends in refinery heat exchanger networks. It can also monitor the effectiveness of chemistries and operating procedures, allowing

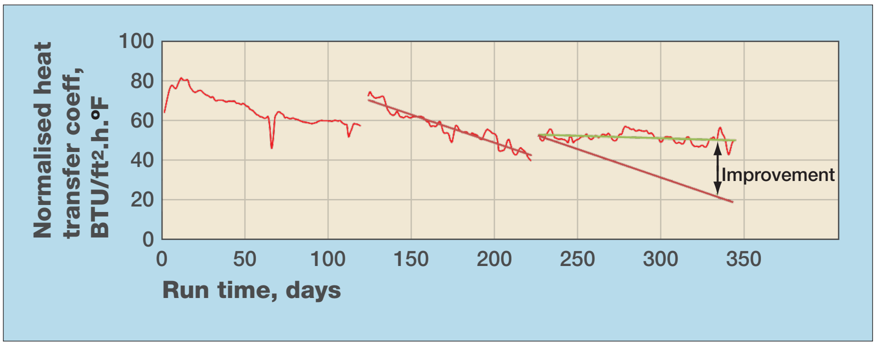

Figure 1 Improved heat transfer on exchanger bundle 1

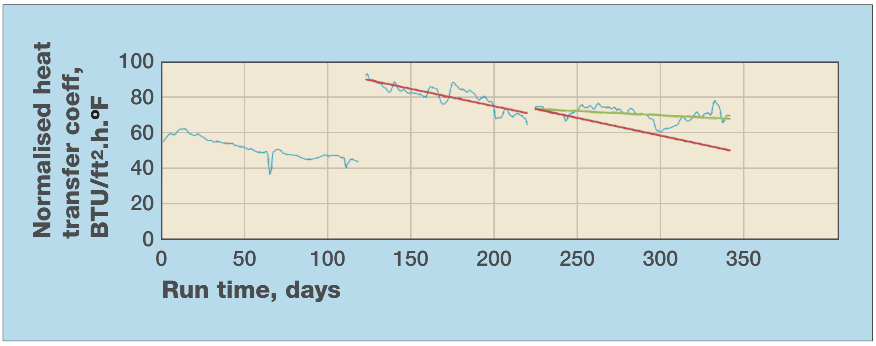

Figure 2 Improved heat transfer on exchanger bundle 2

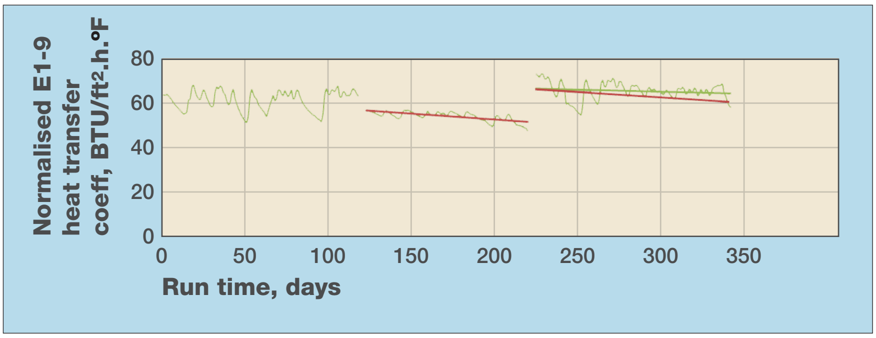

Figure 3 Improved heat transfer on exchanger bundle 4

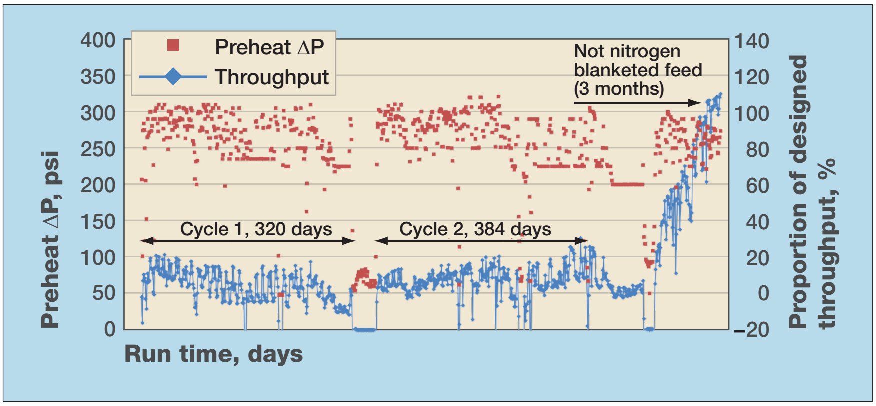

Figure 4 Rapid fouling because the storage tank was not nitrogen blanketed

refiners to select the most appropriate and economical strategy to meet their energy management goals. The network was prepared in Monitor so that the heat transfer coefficient for the individual heat exchanger sets could be trended over time.

Figures 1, **2** and **3** show the rate of decline of the exchanger heat transfer coefficient for three heat exchanger sets. The three cycles represent separate four-month runs with clean heat exchangers. The last cycle is after implementation of the new chemical treatment programme. The new programme showed an over 60% improvement in normalised heat transfer coefficient (U) for bundle 1.

Extending the run length and reducing cleanings resulted in $6 000 000 in total cost of operation (TCO) improvements. With the significant performance gains of the new antifoulant programme realised, the refinery agreed to continue with the upgraded fouling control programme permanently.

Case study 2

A North American refinery was looking to extend the run length between exchanger cleaning of its hydrotreater. This hydrotreater was averaging 11-12 months of run time before the F/E exchangers needed to be cleaned. The cleaning process required a complete unit shutdown. The refiner was keen to extend that cycle to over two years.

The fouling impact also restricted feed rate, with the unit running at approximately 75% capacity. Furthermore, in the past, fouling rates were so high they had caused the unit to be shut down for cleaning after only a three-month run. Due to the severity of the fouling, a combination of antifoulant and antipolymerant was proposed.

Solution

The immediate goal was to identify the cause of this rapid fouling as shown by the increase in pressure drop (dP) across exchangers (see **Figure 4**). The feed to the hydrotreater came directly from other processing units without any intermediate storage. During the previous shutdown, the feed had to be stored in a temporary storage tank. The local Nalco Champion team, in collaboration with the refinery's engineering group, discovered that the storage tanks were not nitrogen blanketed, leading to polymerisation. Processing that feed after the unit restart led to a rapid fouling event which resulted in a lower than expected run length of three months. Because of the Nalco Champion site team's participation in the refinery's root cause failure analysis (RCFA), a proposed treat-

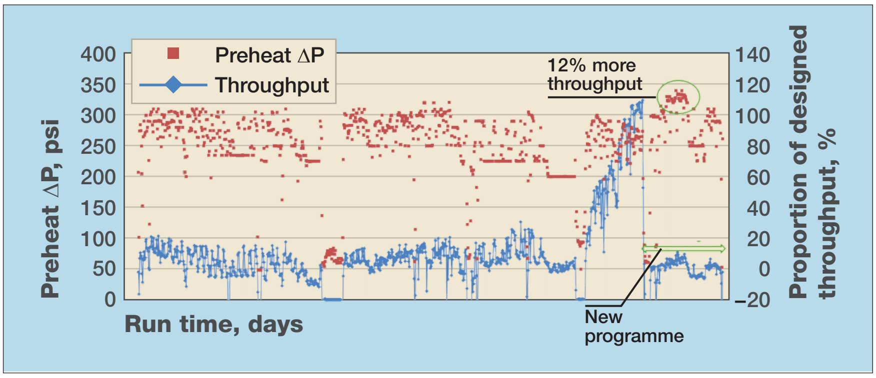

Figure 5 Lower pressure drop and increased throughput

Scenario	No. of days	Ave. BPD	Ave. dP	Ave. dP (flow adjusted)
Cycle 1 (base)	302	=	=	=
Cycle 2	384	-3%	+12%	+23%
New programme	119+ ongoing	+12%	-13%	-31%

Average throughput increased by 12% while dP reduced by 31%

Table 1

ment programme was implemented to help prevent rapid increase in dP from happening in the future.

Results

During the three months after starting up with the new programme, the refiner was able to process 12% more feed, meet increased demand, and reach a new charge rate record (see **Figure 5**). The hydrotreater was able to run more consistently above design, doing so at 38% of the time.

Along with the higher throughput, the new treatment programme produced lower pressure drop (dP) across the heat exchangers by 31% (see **Table 1**) – a significant improvement.

This refiner appreciated the problem-solving path that Nalco Champion took as part of the RCFA. With good communication and leverage of R&D resources and experience, a representative fouling study was first identified to reflect the process conditions causing the rapid pressure drop that led to shutting down the hydrotreater in just three months. The new upgraded antifoulant treatment programme has successfully and consistently lowered the dP across the F/E exchangers while allowing the refiner to increase throughput for an extended period, which represents additional $3 500 000 performance gains. The refiner adopted the treatment approach and made the new programme permanent.

Conclusion

Nalco Champion has developed innovative antifoulant chemistries designed to help refineries effectively mitigate the higher fouling impact on hydrotreating units due to current and pending regulation changes. The case studies discussed in this article have covered some of the real benefits from implementation of the new antifoulant treatment programmes. These examples show significant improvements in extending unit run length, reduced pressure drop, and increased throughput.

References

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