Case Study 305

The Long-term Performance of an Online Process MRA for Enhanced Steam Cracker Optimisation

The Process MRA Site: BASF Ludwigshafen

Case Study Objectives
To evaluate the long-term performance and reliability of online Olefins feed analyser based on the measurement principles of Magnetic Resonance. To reassess the economics of the project based on user experience.

Potential Users
Steam Cracker, Reformer or Aromatics operations that require feed characterisation as part of a project to maximise the profitability of the unit. It is seen as essential to those users who have variable product demands and feed quality specifications

Investment Cost
R.O.I within BASF investment guidlines (2000 pricing)

Savings Achieved
Measurable & Sustainable savings achieved within BASF investment criteria.

These additional savings above the base case of measurement achieved from existing process chromatograph, on a single steam cracker feed.

Case Study Summary

The Process MRA solution has now been functioning online for over two years. Providing feed forward stream characterisation since September 2000 to the Steam cracker reactor model. A Spyro Model from Technip / KTI.

The Steam Crackers (2), are the "heart" of the BASF AG Ludwigshafen integrated chemicals site in Germany.

The project involved the integration of feed characterisation from Process MRA and ROMeo Optimisation software, to improve the operational efficiency and reliability of this site critical operation.

BASF AG operates the crackers mainly for captive use since logistically they are at the end of the pipeline.

Working in partnership with BASF AG, INVENSYS Process Systems GmbH supplied a measurement solution that has now been successfully extended to include both crackers including naphtha recycle streams. The availability has been high (>98%). With prediction models being updated remotely (typically once per quarter) as part of the inclusive three year support agreement.

The measurements cover some 29 components plus 4 calculations from c4 – c11, including Paraffins, iso-paraffins, Naphthenes and Aromatics.

Host Organisation
BASF Aktiengesellschaft
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Project Rationale

The BASF AG Ludwigshafen crackers produce in excess of 610,000 Tonnes of ethylene, and other products mainly for internal consumption. They aim for 365 days per year operation with extended cracker shutdown every five years. These are the hearts of the integrated chemical site and feed characterisation in the form of Gas Chromatography has been used for proper unit operation for a number of years.

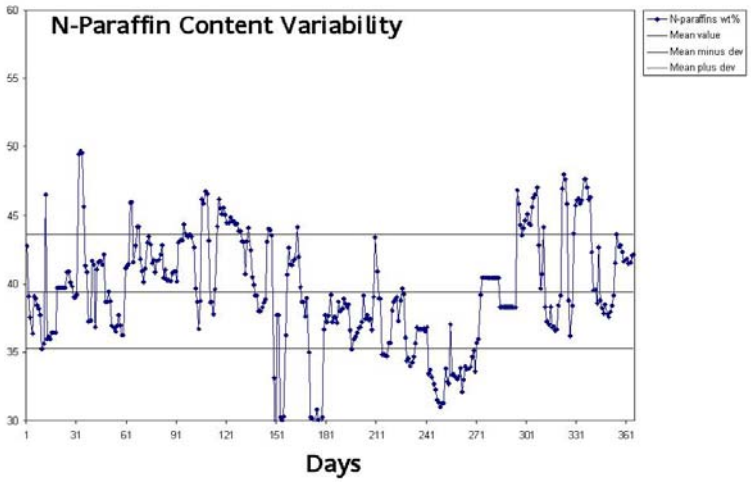
BASF AG purchases Naphtha of variable feed specification, depending on strategic or tactical requirements. Over 140 Naphtha types are regularly used. With tank stratification and regular feed tank changes, good monitoring of feed quality is essential to minimise lost production during feed transitions and to maintain stable operation in the case of a "slug" of high variability Naphtha potentially violating a constraint. Heavy Naphthas could violate Coil Outlet temperature, causing excess coking or tube wall damage, Whilst a Light Naphtha could exceed downstream compressor loading.

However since the GC's were slow to respond (measurement more than one hour), and had a high maintenance overhead, all constraints could not be fully filled. A more frequent analysis and technology requiring less maintenance was required to enhance the project being executed. This would allow constraints to be filled, reduce coil outlet temperature and Severity variability, optimise the yields of the most valuable products and in time allow greater feed variability and flexibility.

A feasibility study investigated a number of options and due to its measurement linearity, fast track project execution and high availability, Process MRA was seen as the online analyser of choice.

The Process MRA System

The Process MRA System is based on magnetic resonance technology utilising high-resolution FT-NMR proton spectra in conjunction with partial least squares modelling techniques to obtain highly linear and robust predictive models. Modelling requirements are limited with single predictive models being used to predict across the entire variability range of each property.



Typical Steam Cracker Feed variability

How does it work?

The technique, developed in the 1950's, reveals the hydrocarbon structure of the fluid being analysed without the need of temperature or chemical pre-conditioning. This is due to the fact that when a hydrogen proton is introduced into a homogeneous magnetic field, the magnetic moments of the protons align with the field. These magnetic moment can be described as vectors. If the sample is then given a short duration radio frequency pulse (at the proton resonant frequency of 58 MHz), the vectors will rotate. A 90^0 rotation yields optimum signal strength. Once the radio frequency pulse has caused a 90^0 rotation the RF pulse is turned off, and the vectors relax back to the original state at a rate dependent on the proton location within the molecular structure. This time dependent "resonance" is picked up in a coil and sent to the NMR receiver as a time dependent signal. If a Fourier Transform (FT) is performed, the structural information is revealed in the resulting spectrum and is commonly known as chemical shift. These shifts have textbook locations and with the use of partial least square regression chemometric software the chemical compositions are correlated to variance of the hydrogen chemistry in the spectrum.

Project Execution

Week 14 & 15
BASF AG was provided with an MRA that measured a starter set of some 100 Naphtha samples spanning the expected operational range. In all less than 50 were incorporated into the final model.
Week 15 to 33
Online system was installed and online model development commenced. A further 75 samples were gathered prior to the decision to run the validation phase.
Week 33 to 36
Validation phase was conducted and the unit was accepted and transitioned to operations.

Operational Experience

The system was installed and commissioned without any disruption to production and within the operational constraints of the local maintenance, engineering and laboratory staff.
Additional daily full chemical analysis was conducted during the project phase.
However since the system has gone closed loop the on-stream time has been very high, with minimal maintenance required from the Cracker department.

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What is the analytical performance?

In general an important measurement of the Naphtha feed is what is known as the Quality Index QI, this is often expressed simply as:

QI = 2 x n-P + i-P + N + 2 – A

Where, nP = normal paraffin content
iP = iso-paraffin content
N = naphthene content
A = aromatic content

Running rigorous test cases has shown that this simple model does not fully express the value available for capture.

Process MRA makes available a higher fidelity measurement, superior in terms of accuracy and precision to that previously available.

Parameter Mean Standard Deviation and Corrrelation

For NMR Predicted Detailed GC-PIONA Analysis

	Mean	SEP	R^2
n-C4,..C10	Client Confidential		
Total n-P	34.10	0.78	0.98
i-C4,...C11	Client Confidential		
Total i-P	32.01	0.66	0.97
Naphthenes	Client Confidential		
Total N	20.4	0.63	0.98
Aromatics	Client Confidential		
Total A	6.66	0.17	0.99

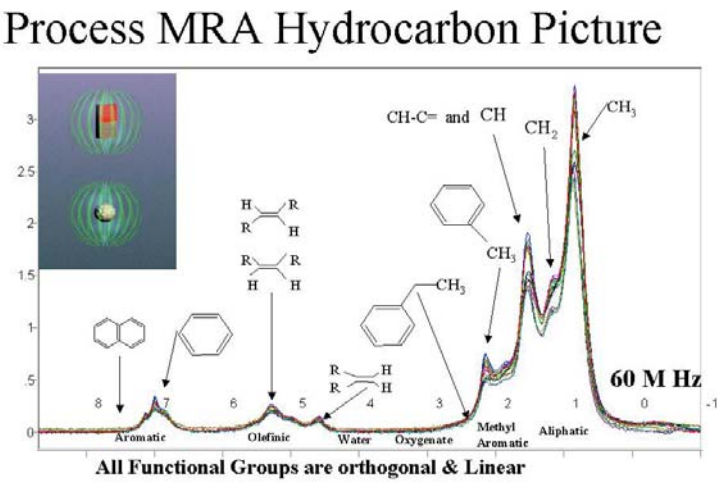
Where Mean is the mean value of the parameter, SEP is the standard error of prediction, and R^2 is the correlation coefficient.

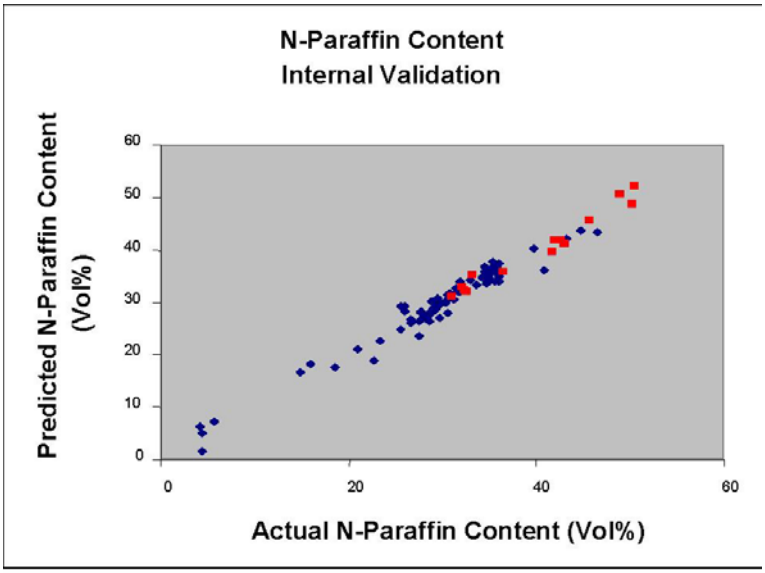
Any Sampling issues?

Since the sampling requirements are straight forward, the system was integrated into the established analyser house for other analytical equipment. Associated with the crackers. No water removal is required and the filtering was set at 100 microns to prevent valve seat damage only. As a note the sample passes through a relatively wide bore 6mm tube.
For the multi stream sampling an in line heater is preferred to clamp stream to stream temperatures to +/- 5^{0}c.

What are the bottom line improvements?

The client will not disclose this, except to say the payback is within the return expected of a BASF capital project.
With reduced soft benefits such as a direct reduction in maintenance and laboratory support for full PIONA GC analysis work





Resultant Linear and Robust Online Process Model

Comments from BASF AG

"This has proven to be a cost effective and worthwhile project. Furthermore we have extended the application beyond the original scope to include feed characterisation of both Cracker feeds plus the Naphtha recycle loops. We required a single model update after installation to achieve results to our demanding specifications.

Invensys took on the responsibility of support of the system for three years from validation and to date we have had a couple of selection valve replacements, a software release update and adjusted the models on average once per quarter. The availability remains above 99%".

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