

Dynamic Simulation for Desulphurisation Plants

Dynamic Simulation of Mild HydroCracking Reactors: Analysis of Reaction Kinetics for Mild Pyrolysis and Desulphurisation

The need for rapid introduction of new desulphurisation processes, to meet ever more demanding reductions in the sulphur content of fuels, has led to the use of more sophisticated dynamic modelling solutions. An example is the Dynamic Simulation that will be used at the new MHC and HDT reactors of Motor Oil Hellas in Greece.

INTRODUCTION

The new, strict environmental constraints for gas and diesel relate mainly to the sulphur content, which, for European Union, has to be decreased to 50ppm after 2005. To reach this specific low standard, and to prepare for the even lower standard of 10ppm that is required by 1st January 2009, refineries have to apply new technologies, in order to increase the total yield of pyrolysis and hydrodesulphurization processes, to reduce the sulphur content of the fuels they produce. The most useful and proven method to produce ultra low sulphur fuels, is through hydrotreatment, both HydroCracking (MHC) and HyDroTreating (HDT) Reactors, where pyrolysis and desulphurization respectively are accomplished.

The new recommended processes are very complicated in their use and these processes demand continuous follow-up from the engineer's side and careful operation from the point of view of the plant operators. By using Dynamic Simulation, detailed models of the new plant can be used to determine the operability of the plant design, and can serve to identify potential control issues, for example shortcomings with the DCS and/or logic. This enables remedial actions, alternative control strategies, or operational procedures to be evaluated and implemented well before start-up.



The simulation of the new unit provides an additional tool with such a precision, that this can be used not only for the optimization of the new process, but also as the Operator Training Simulator (OTS), for existing operators to learn the operation of the new unit, and to be used throughout the plant lifecycle to train new operating crews. OTS systems can result in fewer operating errors and quicker and safer start-ups and shutdowns; improve plant reliability due to improved response to abnormal situations; and can help optimize throughput and product quality.

A unit with MHC and HDT Reactors has already been installed and is soon going to operate at the Corinth Refinery of Motor Oil Hellas (MOH). This article presents the dynamic simulation method applied by Hyperion Systems Engineering, for MHC and HDT reactors at MOH, together with a brief description of the process unit, as well as the short-term and long-term benefits derived from this project.

DESCRIPTION OF PLANT OPERATING CONDITIONS

The unit includes one MHC reactor with conversion of 30% vol in naphtha and diesel and one HDT reactor. The design feed is 227 MT/hr of vacuum distillate for the first reactor and 190 MT/hr of hydrocarbons mixture (vacuum distillate, atmospheric distillate, saturated and unsaturated naphtha) for the second one. The lowest possible feed for a normal operation, the turndown capacity, is 60% of the design feed. It is possible to operate the reactors with a lower conversion (till 20% vol), without affecting the quality of the products. The unit operates under high-pressure, 96 kg/cm² for MHC Reactor and 112 kg/cm² for HDT Reactor, while the reaction temperatures are 367 °C and 330 °C respectively. After the reactors, a series of distillation columns follows, where the different products are being separated.

Specifically, the outlet stream of MHC enters a stripper for the removal of H₂S. The stripped product is distilled at atmospheric pressure and is fractionated to un-stabilized naphtha, diesel and desulphurised feed for the existing Fluid Catalytic Cracking (FCC) unit. The diesel fraction feeds the HDT reactor, while naphtha is stabilised in a suitable column, and; then it feeds the hydrogen production unit. The desulphurised diesel from the HDT reactor, separated from H₂S and naphtha that are produced within the process, is dehydrated under vacuum and composes the final product. The unit includes also two amine scrubbers for cleaning H₂ and the fuel gas from H₂S. H₂ is recycled via a centrifugal compressor, while its losses are being replenished by a multi-stage reciprocating compressor.

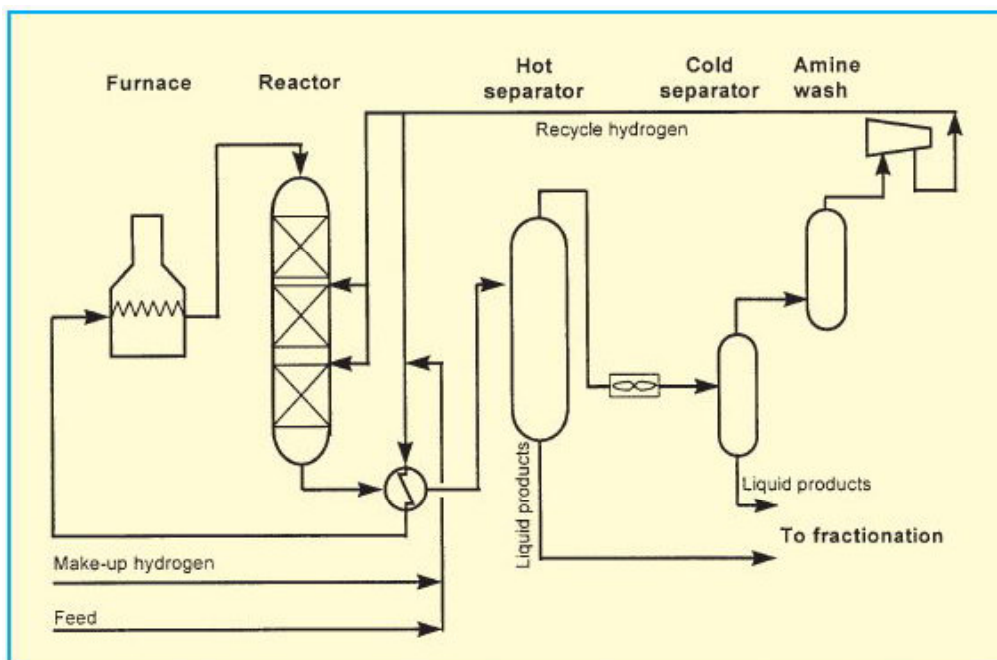


Figure 1: Typical flowsheet of mild hydroprocessing

IMPLEMENTATION OF DYNAMIC SIMULATION - PROBLEMS AND SOLUTIONS

The modelling of the MHC and HDT Reactors, presents the following characteristics:

- ❑ The reactions taking place are complicated.
- ❑ The mathematical systems of equations had to be resolved in real time, with precision.

The existing special simulation software for the specific processes, usually requires significant computational time to compute the products and the outlet conditions of the reactors, thus it could not be used for the increased complexity and precision required for the MHC and HDT reactors. The solution applied finally consists of the following steps:

- a) Modeling of MHC and HDT Reactors by using the high fidelity model of the AspenTech AspenHydrocracker™ software. Operating parameters that have been chosen were:
 - The temperatures of the catalyst beds of the reactors
 - Partial pressure of hydrogen
 - Residence time of the reactants in the reactor
 - Type of Feed, characterised by the following parameters:
 - API SG (Specific Gravity)
 - Percentage of Sulphur Content
 - Percentage of Nitrogen Content
 - Boiling Curve
 - Characterisation of the Feed as paraffin, aromatics etc.
 - Catalyst
 - Type of Catalyst
 - Catalyst's activity vs. the duration of its use
 - Catalyst's poisoning from metals and carbon monoxide (CO).
- b) Step changes were carried out in each of the aforementioned operating parameters, by keeping the rest of the parameters constant. For all the reactions taking place within the reactors, yield shifts' variations for each component were calculated by using the AspenHydrocracker™ model.
- c) The results taken have been grouped into separate tables, one for each catalytic bed of the two reactors. The step changes carried out were confined within the operating limits of the specific unit.

	Yield Shift per Component for API 16.25 minus Yield Shift per Component for API 16.5	Yield Shift per Component for API 16.5 minus Yield Shift per Component for API 16.75
Hydrogen	-1.09E-05	-9.57E-06
Hydrogen Sulphide	5.36E-05	-4.88E-05
Ammonia	2.48E-07	4.65E-07
Water	0	0
MDEA	0	0

Table 1: Variation of Yield Shift per Component against the Variation of Specific Gravity (API) by 0.25, by keeping the rest of the operating parameters constant

- d) The results included in these tables, were imported into the AspenTech HYSYS™ software, in order to be used for the calculation of all the components' total yield shifts. The calculation was carried out by the summation of the individual yield shifts at the specific operating conditions. In this way the time consuming calculations have been executed beforehand and the simulation uses their results straightforwardly, quickly and with high precision.

The dynamic simulator was completed by modeling, in detail, the mechanical equipment and the control systems surrounding the reactor of the unit. The reliability and fidelity of the simulator can be proven through the comparison of the steady state of the operation unit with the design data.

RESULTS

The dynamic simulator was specifically designed for Motor Oil Hellas and was delivered by the end of 2004. Apart from the process simulation, the Emergency ShutDown system (ESD) of the operation unit has also been completely modeled. The final model can achieve up to five times the real time speed. The communication of the model with the DCS (Distributed Control System) of the simulator, which is a copy of the real DCS of the unit, is bi-directional. Thereby, the results of the computations of the simulator appear as indications on DCS consoles and all the manipulations of the operators influence the model exactly the same as in the real plant.

The operators are already being trained on the following entities:

- Familiarization with the normal operation of the unit.
- Response of the unit to disturbances.
- Variation of the products' properties with respect to the operational parameters.
- Application of the normal start-up and shutdown operations.
- Application of emergency shutdown operation of the unit.
- Dealing with equipment malfunctions.

BENEFITS

The simulator has been widely accepted by the operating staff of the unit mainly thanks to the model's fidelity. The specific method used to model the system's reactors offers the required fidelity via analytical and detailed solution methods in real time, so that the results can be used not only for analysis and process optimization, but also as a tool of learning the operation of this new process.

The expected benefits are:

- Control of the normal process of start-up and shutdown of the unit.
- Reduction of the required time for normal start-up and shutdown of the unit.
- Increase in the continuous operation time.
- Increase in the operational time between sequential catalyst changes, by avoiding unsafe operational conditions.
- Continuous improvement of the real-time control system of the unit. The desired modifications can initially be tested on the simulator in different operating conditions, before being implemented operationally.
- The probability of a severe incident occurring during the unit operation is reduced.
- The impacts on the environment are reduced by avoiding an abnormal operation of the unit.

ABOUT HYPERION

Hyperion Systems Engineering Ltd. has one of the world's most experienced teams of resource in the field of Dynamic Simulation and Operator Training (OTS), with in excess of 50 simulation and modelling professionals, and OTS projects implemented throughout the world.

Hyperion has an exclusive, worldwide, OTS partnership agreement with Invensys SimSci-Esscor, and offers leading edge OTS simulation solutions based on SIM4ME and DYN SIM technology. Hyperion also offers Application Support Services for existing installed OTS systems. ARC Advisory Group rates the combination of Hyperion and SimSci-Esscor as one of the world's largest suppliers of OTS services to the Chemical, Oil & Gas, and Power Generation industries.

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