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Troubleshooting liquid carryover in gas compression systems

Exploit the links between MySep and Aspen HYSYS® to understand and remedy loss of production

Cris Heijckers, Director, MySep Pte Ltd

Tom Ralston, MySep Pte Ltd

MySep Pte Ltd
1 Coleman Street
#05-06A The Adelphi Building
Singapore 179803

Email: info@mysep.com
Web: www.mysep.com
Follow on LinkedIn

INTRODUCTION

Process simulation is a powerful tool to assist in optimising process operations and in understanding bottlenecks where equipment is operating below expectations. To be effective for these purposes, simple models of process unit operations need to be replaced by models with appropriate rigour to represent actual equipment behaviour. The following case study on troubleshooting a production gas compression installation on a production platform handling gas, produced water and heavy crude demonstrates:

- The technical and financial importance of having vessel performance accounted for in process simulations
- How process simulations become more representative using the bi-directional link between MySep and Aspen HYSYS®
- How rigorous modelling of MySep provides a basis for remedying excessive carry-over

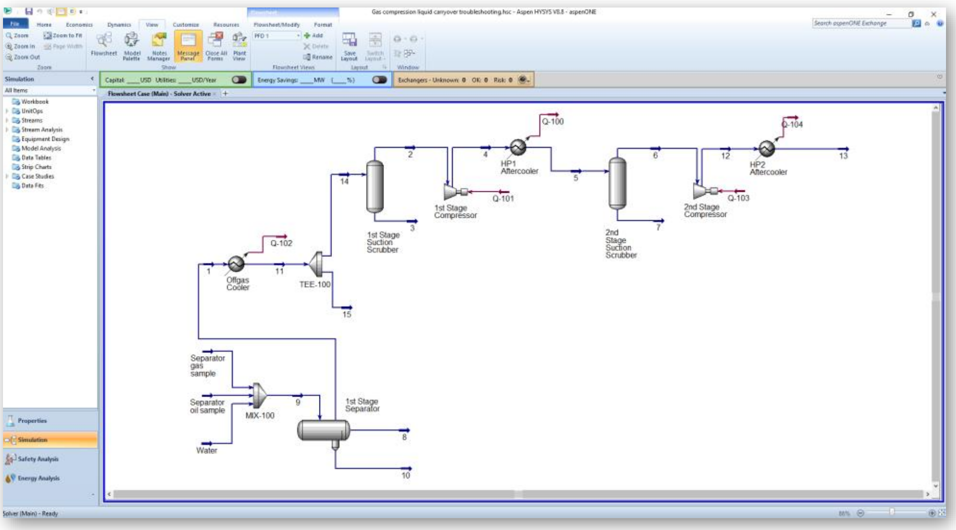
SUMMARY

- HYSYS and MySep working together reveal actual process behaviour
- A case study illustrating an oil and gas production application
- Poor performance in a gas compression system resulted in lost production worth $160k/day
- MySep and HYSYS diagnose cause of compressor fouling and remedy
- MySep modelling validated by level trend data

Process Modelling

Process simulators are widely used in the oil and gas industry to analyse process behaviour and diagnose problems with the aim of optimising operations. Simulators such as HYSYS, provide overall modelling of the process including characterisation of process fluids and models for unit operations that represent the behaviour of different types of equipment. For the case study considered here the HYSYS process flow diagram is illustrated below.

Figure 1 HYSYS and the Process Flow Diagram



Phase-separators for two-phase (gas-liquid) and three phase (normally a hydrocarbon liquid phase, an aqueous liquid phase and a gas phase) are employed in many different processes. They are at the heart of oil and gas production but are also critical in downstream processes including: crude distillation and associated refinery processing; LNG; Gas Processing; Petrochemicals; bulk organic and inorganic chemical production. Typically, in process simulations separators are designated as 100% efficient, implying, for example, that there will be no carry-over of liquid droplets entrained in gas flow leaving a separator. In practice some degree of carry-over will almost always occur and as will be seen in the case study presented here, even small quantities of liquid in gas can have serious consequences in many process applications.

Production Compression Systems

In an offshore production system, such as the subject of the case study here, oil and water are separated from the gas flow in a 3-phase primary separator. To export the gas, it is necessary to increase its pressure in a compression system. This is usually achieved in 2 or more compression stages with pre-cooling and inter-cooling. Compressor blading is sensitive to erosion damage and fouling of the blades will affect performance. As a result, suction separators (or scrubbers) are normally provided to minimise the quantity and the size of liquid droplets entrained in the suction of the compressors.

Business Problem

The process, in this instance, was the primary separation of oil, water and gas on an offshore production platform and gas compression for export. The main elements of the process were modelled in HYSYS as seen in Figure 1 above.

The 1st Stage Separator removes oil and produced water before the gas is passed through two parallel compression trains. In the HYSYS simulation only 1 train was modelled. The low pressure and high pressure compression stages are preceded by pre-cooling and suction scrubbers.

The operator monitored the performance of the compression systems, measuring throughput of gas and both temperature and pressure at compressor suction and discharge for each stage. Over time a progressive reduction in polytropic efficiency and polytropic head was observed with most serious impact on the 2^{nd} stage compressors in both Train A and Train B. This effectively resulted in a loss of production due to reduced gas mass throughput in the export pipeline and also some reduction in oil production.

Inspection of the compressors revealed that there was build-up of contamination on the impellers, which proved to be thermally

ECONOMIC ANALYSIS

Considering 120 MMSCFD gas production capacity

- Daily lost production of 32 MMSCF (assuming minimal impact on oil production)
- Cost of lost production $59MM per year
- Cost of new internals to remediate each train: $750k
- Facility shutdown and recommissioning cost: $6.8MM
- Total cost of remediation: $7.5MM
- Project payback time: 47 days

degraded crude oil. Counterintuitively, the performance deterioration and fouling were noticeably more severe in the 2nd Stage Compressor than in the 1st Stage Compressor.

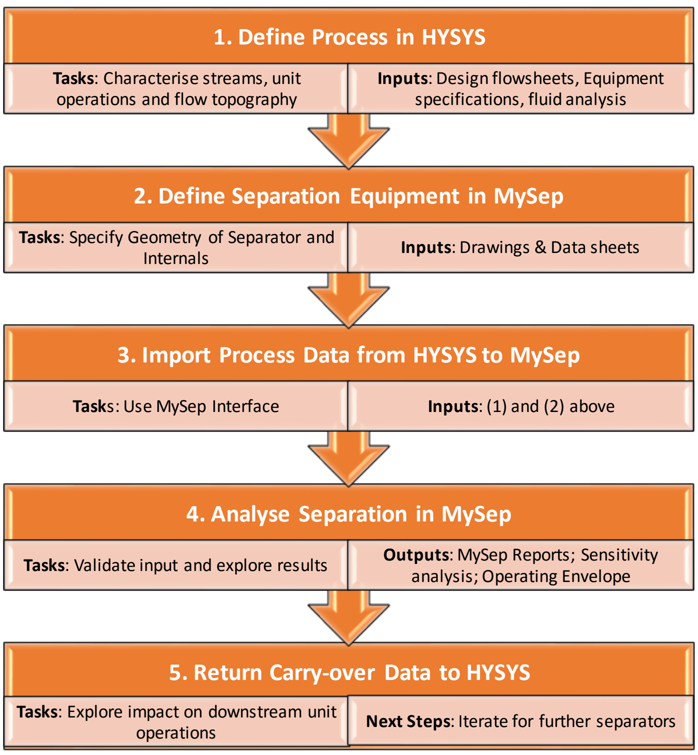
ANALYSING WITH HYSYS AND MYSEP

Generally, when simulating a real process, the starting point is specification of the process streams characterised by their composition and appropriate thermodynamic models for prediction of properties and process conditions. Definition of the process flow topography and main unit operations allows calculation of overall heat and material balance and estimates of energy flows. Simple models of each unit operation can be replaced by more rigorous models to represent real equipment behaviour, for example the compressor performance curves can be directly input to facilitate accurate prediction of pressure ratio and power consumption.

Normally for phase separators, the engineer will start by assuming 100% efficiency. This effectively prescribes that there is no entrainment of one phase into another at the respective outlets. The user may readily specify carry-over directly. It is however very challenging to find a reliable basis on which to predict the amount of carry over or the droplet sizes to be expected in the absence of a program like MySep.

MySep can predict carry-over of liquid in gas and of the dispersed liquid phase with the continuous liquid phase using internal models which are founded upon exhaustive research.

Figure 2. Overall Troubleshooting Workflow with HYSYS and MySep



A separator can readily be defined in MySep with all common configurations of internal separation components.

The program has a simple interface to HYSYS that allows rapid transfer of process and phase property information and MySep also allows users to transfer predicted carry-over information back to the simulator.

In short, the combination of MySep and HYSYS gives the process engineer the means to properly evaluate separator behaviour and the impact this will have on the process.

The overall work flow for separator troubleshooting analysis can be defined as shown in Figure 2.

MySep Setup & HYSYS Communication

In the sections which follow we will describe how HYSYS and MySep work together and refer to the steps in the workflow diagram enumerated above.

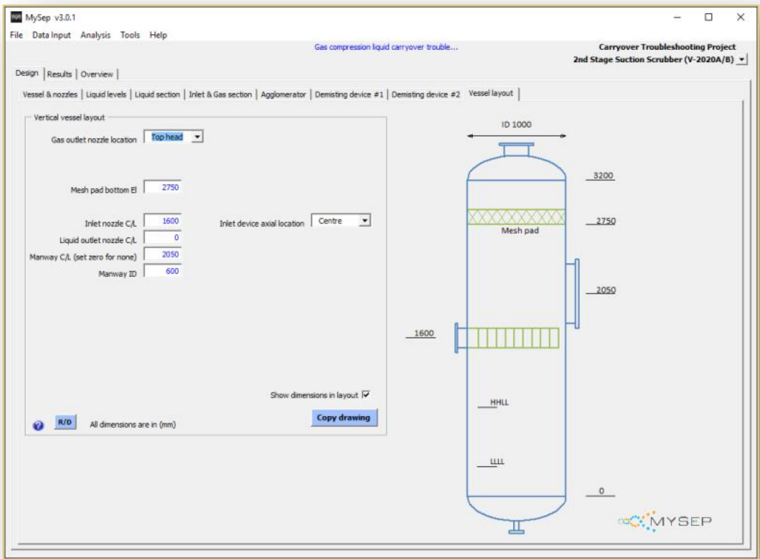
Workflow Step 1: As we have seen in in Figure 1, the process forming the subject of our particular case study is already defined in a HYSYS flowsheet.

Workflow Step 2: Under the major category of "Design," MySep provides the user with a series of tabbed forms, shown below, to define the configuration of a vessel and the separation devices enclosed within it.

Figure 3. MySep Tabbed Forms

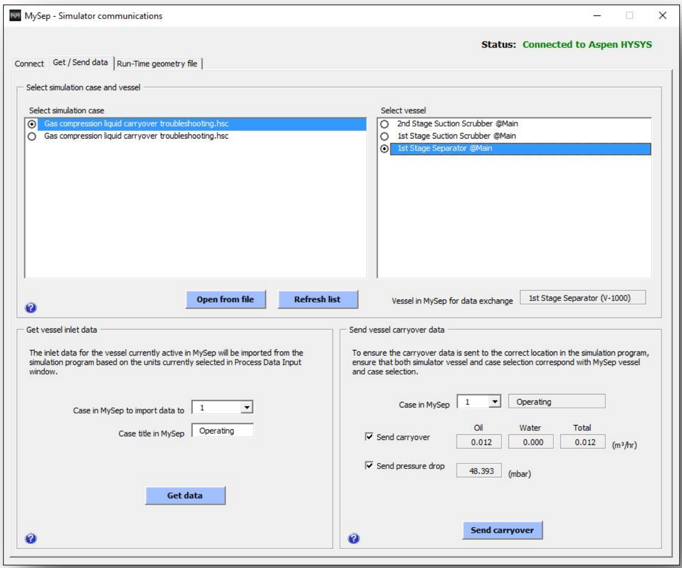
The user steps through all the tabs defining the selection and precise geometry of individual internal devices until the entire separator is configured. The analysis requires the liquid control levels to also be specified since these influence both gas-liquid and liquid-liquid separation. Once the separator is fully configured, including the location of nozzles and internal devices, a scale diagram of the assembly is available to validate the geometry, as shown below.

Figure 4. MySep Vessel Layout Form



Workflow Step 3: Using the Data Input menu of MySep we can open the Process data forms, to manually enter values or we may choose to import data from a simulator. Here we can select a HYSYS case, by name, which is open on our computer or we may choose to open a saved HYSYS file. MySep interrogates the HYSYS case and provides a list of separator unit operations so that we can select the one we wish to model in MySep. The Simulator communications form is illustrated in Figure 5.

Figure 5. MySep Simulator Communications Form HYSYS and MySep



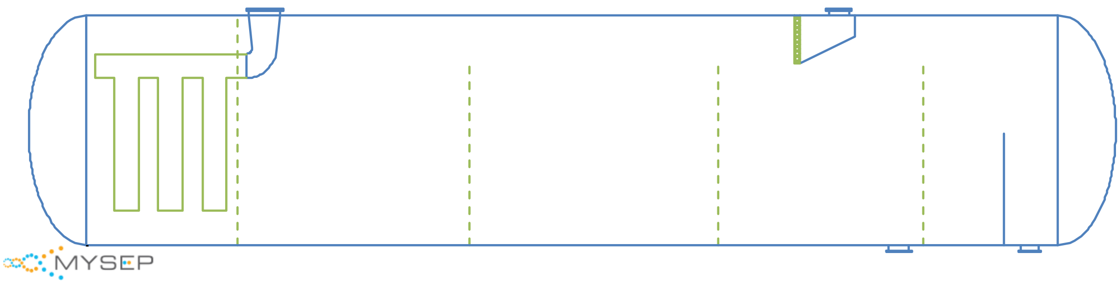
TROUBLESHOOTING CASE STUDY

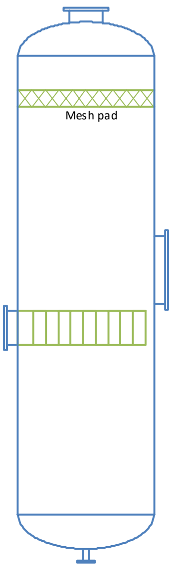
The MySep Models

A steady state simulation of the system was set up in HYSYS, as described above, with operating conditions set to replicate those in the field. Subsequently, vessel arrangement drawings were used to replicate the 3 separation vessels and their internals in MySep.

The 1st Stage separator is a 3-phase device, arranged horizontally, with inlet cyclones and a mesh-type demister as illustrated below. Flow conditioning baffles are provided in addition to a bulk liquid separation weir.

Figure 6. MySep 1st Stage Separator Layout Sketch



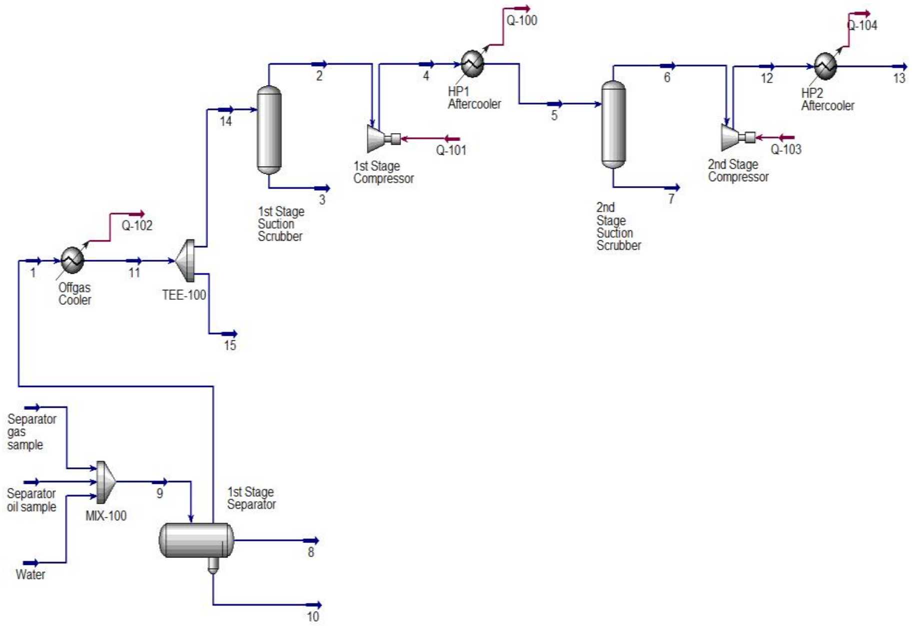


The 1st and 2nd Stage Suction Scrubbers are vertical vessels, each fitted with a vane-type inlet device and a mesh-type demister as shown in Figure 7.

Figure 7. MySep 1st Stage Suction Scrubber Layout Sketch

The HYSYS Model

Figure 8. MySep 1st HYSYS Process Flow Diagram Detail



Initially, as we have described, the "Carry Over Model" in HYSYS was set to its default value: "None". This means that the separation efficiency of the vessels in the simulation is assumed to be 100%. Consequently, none of the liquids entering the 1st Stage Separator are predicted to leave with the gas (stream 1) which feeds the A and B compression trains. Similarly, the gas outlet streams from both Suction Scrubbers are predicted to be free of liquids.

In reality, however, as we have described, clear evidence had been found of crude oil fractions penetrating into the compressor trains.

The operator was unclear as to how this was occurring and also why the 2nd stage compressors were more severely affected.

Addition of MySep Analysis

To make our modelling physically representative we use the bi-directional link between MySep and HYSYS. For each vessel in the simulation, the inlet stream data is pulled into MySep and the calculated carryover is pushed from MySep back to the outlet stream of the vessel in HYSYS. The carryover is calculated automatically by MySep on the basis of the previously entered geometries, liquid level settings, internals types and dimensions applying MySep's intrinsic models and correlations.

Workflow Step 4: Considering each separator in turn within the MySep program with the appropriate process data from HYSYS. The 1st Stage Separator proved to be performing very well with MySep predicting a carryover of 12 l/hr. Imposing this liquid load to the two trains (the Offgas Cooler was bypassed), the carryover from the 1st Stage Suction Scrubber was predicted to be approximately 2 l/hr.

MYSEP VALIDATION

From level trends, liquid accumulation rates in 1st stage suction scrubbers of Train A and Train B were derived

- Measured carry-over from 1st Stage Separator was 11.7 l/hr
- MySep predicted carry-over is 12 l/hr
- MySep prediction in very close agreement with field data

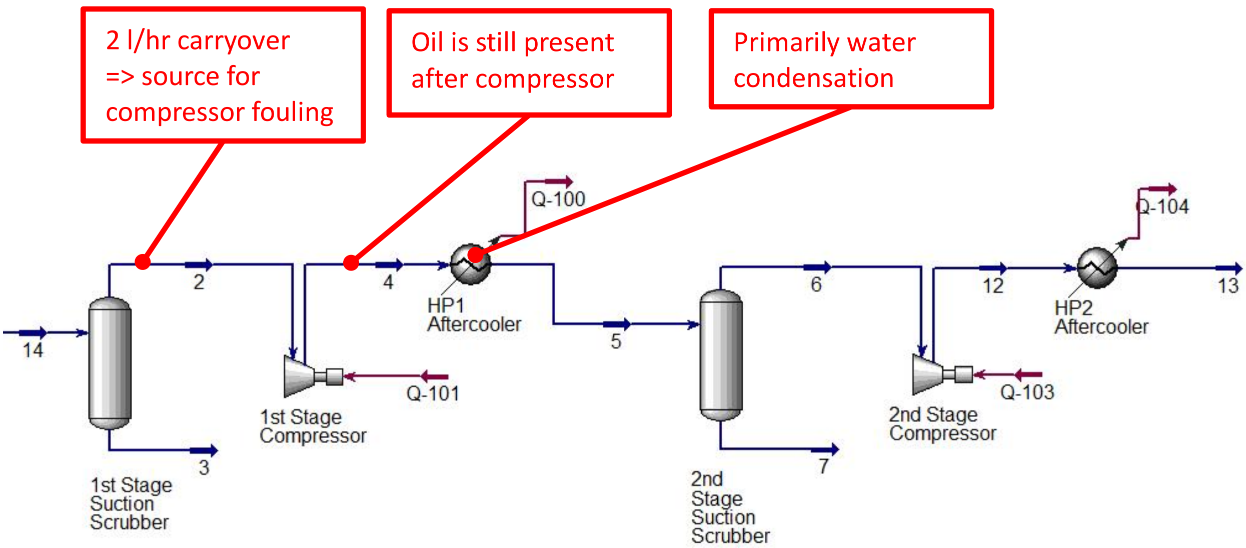
The analysis offers verification of the carryover predicted by MySep for the 1st Stage Separator with reference to field data. This was done by determining the liquid accumulation rates in the two 1st Stage Suction Scrubbers from liquid level trend data logged on a data historian. The 1st Stage Suction Scrubbers of Train A and B had an accumulation rate of 4.24 l/hr and 5.42 l/hr, respectively. These values are in effect the separated liquid flow rates. Using these numbers, the liquid load to the scrubbers was iteratively calculated based on the associated separation efficiency of the vessels and this yielded a value of 11.7 l/hr.

The 1st Stage Separator carry-over predicted by MySep was 12 l/hr. It can be seen to be in very close agreement with the measured liquid load to both compressor trains.

Returning Carry-over Predictions to HYSYS

Once the carryover from the 1st Stage Suction Scrubber predicted by MySep (2 l/hr) was sent to the HYSYS simulation, corresponding to **Workflow Step 5**, an important observation was made: The simulation predicted that this carryover only partially evaporates in the 1st Stage Compressor. This means that the compressor outlet stream (stream 4) contains hydrocarbons in liquid form. This prediction is supported by the fact that in the field oil has been found further downstream, e.g. in the 2nd Stage Suction Scrubber.

Figure 9. Analysis of Liquid Carry-over from 1st Stage Suction Scrubbers



The HYSYS simulation also predicts that primarily water condenses out in the 1st Stage Aftercooler (0.257 m³/hr). Applying a similar approach as for the 1st Stage Suction Scrubber, the liquid load to the 2nd Stage Suction

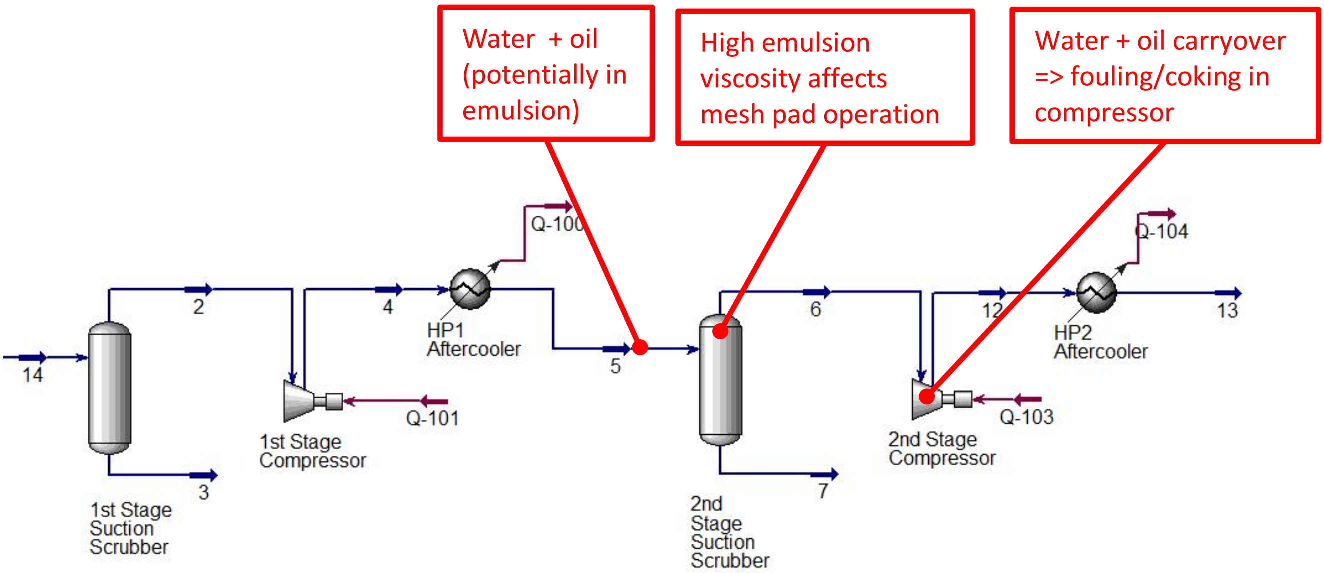
Scrubber was determined from field level trend data: 0.262 m³/hr. The measured and predicted flow rates are thus in good agreement.

The simulation finds that the liquid in the 2nd Stage Suction Scrubber inlet stream (stream 5) contains primarily water with some oil. It is known that the subject oil has a tendency to create emulsions with water. The 1st Stage Aftercooler was a Printed Circuit Heat Exchanger which consists of many narrow flow channels. At the outlet these channels discharge into a header with significant shear that has been known to promote emulsification if certain other conditions combine unfavourably. Postulating that under operating conditions prevailing here, the oil forms an emulsion with the water condensed in the intercooler and recognising that the viscosity of an emulsion is typically significantly higher than the viscosity of the individual phases would explain significant carry-over from the 2nd Stage Suction Scrubber.

The liquid viscosity has a direct impact on the flooding point of a mesh pad, as fitted in the 2nd Stage Suction Scrubber. The flooding point of a mesh pad are the conditions beyond which separated liquid is re-entrained at the rear (outlet) face of the mesh pad, effectively when it is beyond its operating envelope as a demisting device. The higher the viscosity, the lower the flooding point of the mesh pad.

Using MySep to analyse the operation of the mesh pad in the 2nd Stage Suction Scrubber it was seen that the size of the mesh pad was suitable to handle the operating gas flow rate based on the liquid viscosity predicted by the simulation (i.e. no emulsion). However, if an emulsion is indeed present, the higher viscosity would result in a reduction in the mesh pad flooding point such that it would be operating above this point at the prevailing gas flow rate. This would result in poor performance of this vessel and significant carryover to the 2nd Stage Compressor, consistent with field observations.

Figure 10. Analysis of 2nd Stage Suction Scrubber



The above analysis shows how the combined use of MySep and HYSYS can reveal critical phenomena in the system that would otherwise remain hidden.

A final question that remains to be answered is why the fouling and performance deterioration was more sever for the 2nd Stage Compressor as compared to the 1st Stage Compressor. After all, less oil reaches the 2nd Stage than the 1st Stage. It was concluded that the presence of water from the 1st Stage Aftercooler and the process conditions prevailing there were likely to generate an oil-water emulsion. This exacerbates the oil fouling/coking process in the compressor.

REMEDIATING EXCESSIVE CARRY OVER

Using MySep to explore retro-fit of alternative internals, it was possible to quickly assess changes to reduce carry-over from the 1st Stage Separator. It was also possible to propose modified internals for the 1st and 2nd Stage Suction Scrubbers.

Changes of this type can be carried out with very rapid payback, incurring lost production from 1 train at a time for installation of around one week. Capital outlay for retro-fit internals of around $750k might be expected with assurance that the compression system will operate without the historic drop in efficiency and pressure ratio.

MySep has unique capability for efficient re-design accessible to any process engineer including:

- Auto-size for initial vessel scope quickly ranking configurations with a range of internals
- Optimisation manually for minimum cost, weight & footprint

A solution could be proposed with improved demisting capacity in the 1st stage separator and introduction of a cyclonic demister, in combination with an appropriate design of mesh pad for the suction scrubbers. This could deal with the high viscosity liquid resulting from emulsification of the heavy crude being produced in this facility.

CONCLUSIONS

This case study demonstrates how HYSYS and MySep, in combination, allow quantitative analysis of separator performance.

It demonstrates that phenomena can be revealed by MySep which are far from apparent to the engineer scrutinising only with instrument data from the process historian and simulations of HYSYS.

The case study further shows validation of MySep carry-over predictions for a 1st Stage separator against operating data.

As well as providing the essential understanding to correctly diagnose the source of operational problems manifesting as poor compressor performance, MySep in conjunction with HYSYS, allows rapid evaluation of remedies to the separation equipment. In this case, changes in separator internals could be accommodated within the existing vessels with minimum capital cost implications and the least interruption to operations.

Combined use of MySep and HYSYS at the design stage is crucial to avoid the costly operational problems such as those shown in this case study. Unfortunately, this case represents experience that is all too common for operating companies across the oil and gas industry.

The addition of the new MySep run-time module which will be released in 2016, makes the evaluation of the impact of process changes on a system of separators and other process units even more accessible to the process engineer.

More information on MySep

MySep extension for process simulators:	www.mysep.com/Videos/RunTime-introduction-video.aspx
Video showing the Motion module:	www.mysep.com/Videos/Motion-video.aspx
User Testimonials:	www.mysep.com/Testimonials.aspx
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