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Application Solution

Summary

Using Dynamic Simulation for HPU Depressuring Analysis, you can:

- Reduce feed effluent heat exchanger design temperatures for new construction projects
- Eliminate requirement to rerate or relocate exchanger for revamp projects
- Eliminate requirement for secured power for the reactor effluent air cooler fans
- Use extruded fins rather than embedded fins for reactor effluent air cooler

Business Value

Dynamic Simulation for high pressure hydrocrackers can predict the maximum metal temperature of feed heat exchanger bundles to reduce their costs. Customers have seen savings from $600K to over $3M using Dynamic Simulation.

SimSci™

Dynamic Simulation Example

HPU Depressuring Analysis

INTRODUCTION

Conventional methods for evaluating the peak exchanger temperatures on high pressure hydrocrackers often result in expensive exchanger designs for new projects. For revamp and de-bottlenecking projects, a reduced margin between new normal operating temperatures and maximum design temperatures may indicate an unnecessary heat exchanger rerating or replacement. Dynamic simulation provides an analysis tool to predict the maximum metal temperature of the feed/effluent heat exchanger bundles to reduce their costs. Dynamic simulation is also used to verify the heat exchanger mechanical design, including the design of the Reactor Effluent Air Cooler (REAC).

DYNAMIC SIMULATION BENEFITS SUMMARY

- Reduce feed effluent heat exchanger design temperatures for new construction projects
- Eliminate requirement to rerate or relocate exchanger for revamp projects
- Eliminate requirement for secured power for the reactor effluent air cooler fans
- Use extruded fins rather than embedded fins for reactor effluent air cooler
- Dynamic Simulation Savings are approximately US$0.6 - 3.0 million[1]

TYPICAL UPSET SCENARIOS

A common scenario is that a unit may be depressured due to high reactor temperature, partial or total power failure, or equipment malfunction. Reactor feed pumps and recycle compressors are stopped and the vent to flare is opened. Typical reactor depressuring time is normally around 15 minutes. Without feed cooling, the reactor effluent heat exchanger temperatures will increase.

A less severe case is loss of feed without a corresponding depressuring. If the unit feed pump trips, the reactor inventory empties through the feed/effluent heat exchangers. This is due to continued recycle gas flow.

The reactor effluent flow may be higher for the depressuring case than the loss of feed case as the unit is depressured through the cold high-pressure separator. However, the exchangers may be able to sustain higher temperatures during a depressuring than a loss of feed case, as the exchanger mechanical stresses are reduced at lower pressures.

DYNAMIC SIMULATION MODEL

Figure 1 shows a representative dynamic simulation model for hydroprocessor depressuring analysis using DYNSIM®, from SimSci-Esscor™. It includes the reactor, effluent exchangers (E1, E2, E3, and E4), the hot high pressure separator HHPS, the reactor effluent heat exchanger E5, and the cold high pressure separator CHPS. The simulation model includes water injection upstream of the reactor effluent air cooler and includes a feed valve XV1, a valve to the recycle compressor XV2, and a depressuring valve to flare XV3.

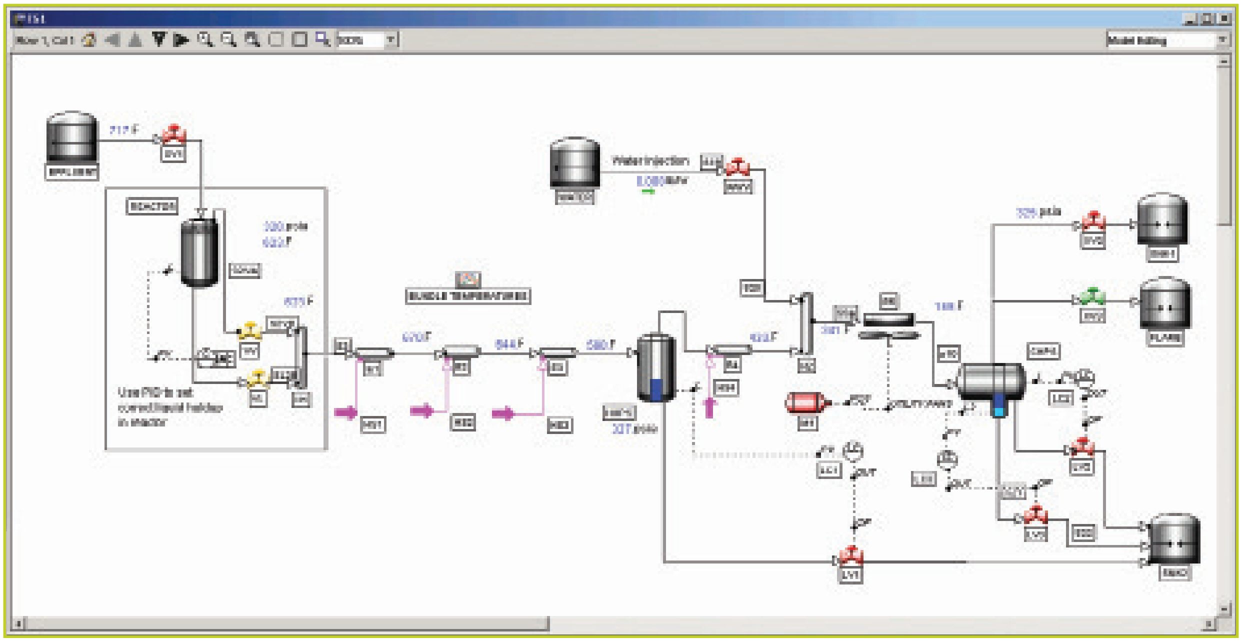


Figure 1: DYNSIM Model

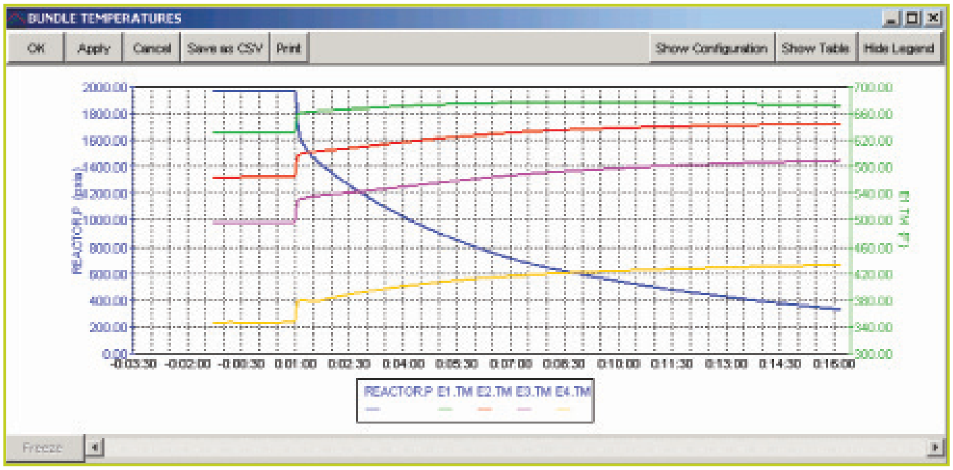
In dynamic simulation, it is not always possible to develop accurate general purpose models that are appropriate with respect to all simulation applications. Therefore, it is important to review the model assumptions for conservatism with respect to the process design objectives. With this strategy in mind, the following conservative modeling assumptions were made for this analysis;

- The reactor is modeled as a single DYNSIM Drum with a vapor and a liquid outlet. A PID controller was used to adjust the vapor liquid outlet ratio to obtain the correct liquid inventory in the reactor prior to depressuring.
- A DYNSIM Pipe model with metal thermal inventory for the tube bundle models each heat exchanger. A heat stream is added to remove the normal operating duty from each pipe. At the time of the depressuring event, each of these heat stream duties is set to zero to simulate the sudden loss of feed cooling. The heat transfer coefficient between the fluid and the tube bundle should be based on a trusted source such as HTRI. The tube bundle mass must also be conservatively estimated. A low value for metal mass is conservative as higher values cause the temperatures to increase more slowly.
- The HHPS and CHPS is modeled with the DYNSIM Separator model with separate holdups for vapor, liquid, and aqueous phases to account for faster vapor temperature transients than liquid temperature transients.
- All vessels are modeled with an isentropic expansion efficiency of zero. This use of an isentropic expansion efficiency allows the vessel depressuring to follow an isenthalpic path, which results in hotter final temperatures than an isentropic path (efficiency of 1.0) used for cryogenic depressuring analysis.
- The flow-through vent to flare valve XV3 is calculated assuming choked flow based on the actual valve Cv and an X_T.

CASE EXECUTION AND RESULTS

A DYNSIM scenario was created to run the simulation case repeatedly during the initial trial runs. The scenario was set up to load a steady state initial condition, wait 60 seconds, and then simultaneously close the feed valve, close the valve to the recycle compressor, open the depressuring vent valve, stop the reactor effluent air cooler motors, and set the heat duty to all of the heat exchangers to zero.

In Figure 2, the drums are depressured from 2000 psia to 400 psia in approximately 15 minutes (blue line). The Green, Red, Purple, and Yellow lines show the increase in effluent exchanger bundle temperatures E1, E2, E3, and E4 respectively.



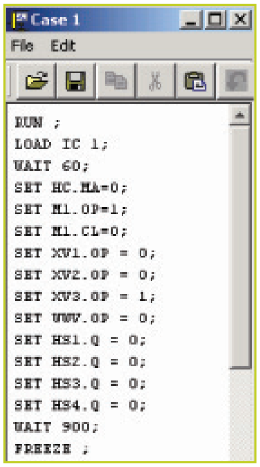


Figure 2: Reactor Pressure and Effluent Exchanger Temperatures

EQUIPMENT DESIGN

Equipment mechanical design is based on the combination of a design temperature and a design pressure. Conventional steady state methods for determining design conditions for hydroprocessing feed/effluent exchangers considers that the heat exchanger temperatures rise instantly to the reactor outlet temperature, such that the exchanger is exposed to the maximum temperature at the normal operating pressure. This conventional approach pairs the two most severe values: the normal operating pressure and the reactor effluent temperature.

According to ASME code, the design of vessels and piping is to be based on the mean metal temperature, not on the temperature of the fluid contacting the metal. Dynamic simulation reduces heat exchanger design temperatures by accounting for the shell and tube bundle metal heat capacitance and the actual liquid inventory in the reactors. Furthermore, dynamic simulation can determine the time required to heat the exchangers while the unit is depressured to develop a coincident temperature and pressure profile, as shown by Figure 3.

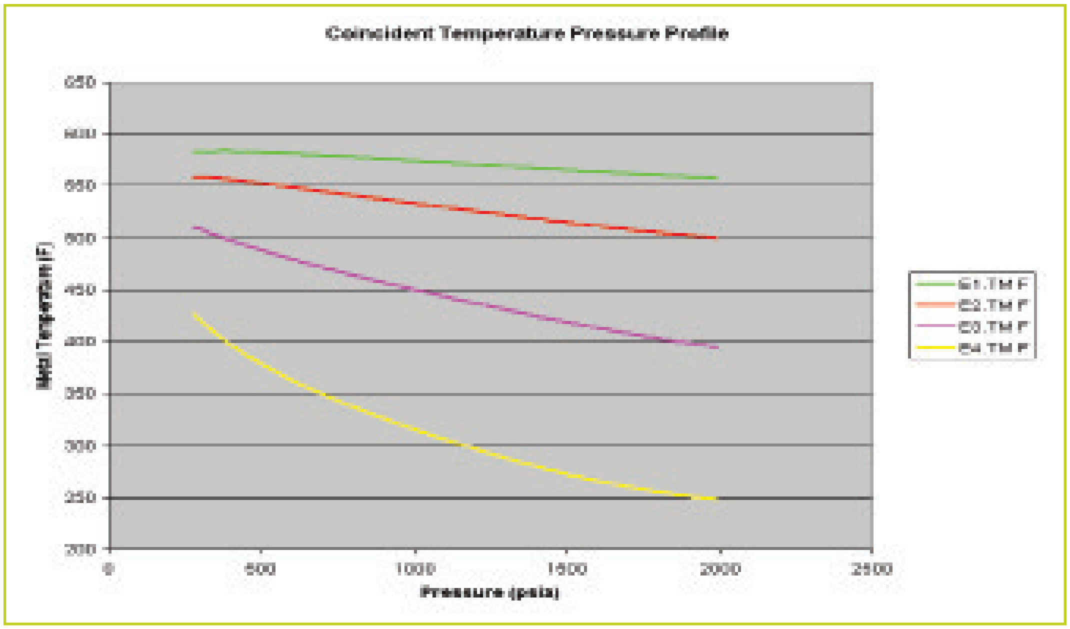


Figure 3: Coincident Temperature and Pressure Profile

Mechanical engineers use this coincident temperature and pressure profile to determine the most severe set of conditions without assuming the maximum possible temperature that occurs at the highest possible pressure. The results of this analysis can have substantial equipment cost savings.[1]

ADDITIONAL MODEL REFINEMENTS

Some additional model modifications can be made for a more thorough analysis.

- Use multiple reactor models to accurately determine the initial reactor inventory.
- For highly exothermic reactors (such as a hydrocracker), add an imposed heat to the reactor fluid during depressuring. Use very conservative assumptions such as all the inventory reacts to methane to develop appropriate results for process design.
- Each exchanger can be broken into multiple zones to calculate heat exchanger shell and tube bundle metal temperature more accurately using the Invensys DYNSIM Multi Exchanger model.

CONTACT INFORMATION

For more information regarding DYNSIM, please contact your local Invensys sales representative.

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1 Depew, Ernest: "Use Dynamic Simulation to Model HPU Reactor Depressuring," Hydrocarbon Processing, January 1995.

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Rev. 12/14 PN SE-0127