

Activated Dynamics for Compressor Surge Analysis in Aspen HYSYS®

A Brief Tutorial (and Supplement to Training and Online Documentation)

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Introduction

Compressors, generally used to increase the pressure of a gas, are an integral part of many production processes in the oil and gas, energy and chemicals industries. They are highly specific to each process for which they are designed. As a result, they are mostly custom-manufactured, expensive and difficult to replace.

Compressors operate with very fast dynamics, and even a slight disturbance to a process's steady state could lead to a compressor surge, which is the point at which a centrifugal compressor cannot add enough energy to overcome the system's backpressure. A compressor surge can lead to the unit malfunctioning, including rapid flow reversals and changes in axial thrust, high vibration and damage to rotor seals and bearings, which could necessitate equipment replacement. Additionally, surge is dangerous for individuals working near the compressor and can lead to a process becoming hazardous, especially if process gas is released to the surrounding atmosphere.

To combat compressor surge, specialized control systems are designed and implemented into processes. Control systems are enacted to maintain fluid flow to the compressor, which keeps the unit from surging.

Predicting which process conditions will cause the compressor unit to surge, and designing the subsequent control scheme is a challenging, involved task. Activated Dynamics in Aspen HYSYS allows users to get started earlier with dynamic analysis of compressor operation to ensure uninterrupted compressor operation.

Activated Dynamics enables users to easily transition from steady-state models to dynamic models to better address costly compressor upset and failure. Pre-made templates for dynamic subflowsheet configuration (with an option to create custom templates) allow users to configure dynamic compressor subflowsheets with one click, including all the necessary equipment and control schemes. Pre-made scenarios and results forms are also automatically generated after converting an existing steady state case to reduce model setup even further. Activated Dynamics provides support for cases involving one-, two- or three-stage compressor systems.

In this jump start guide, analyzing the dynamic surge response of a compressor with just a few clicks using Activated Dynamics will be explored.

While this guide will walk the reader through the process of using Activated Dynamics to get started with dynamics modeling compressor performance, AspenTech recommends that a range of other resources be called upon in conjunction with this document to give the user a comprehensive view of how to use Aspen HYSYS.

These may include:

- The AspenTech support website (esupport.aspentech.com), which has a wealth of information on the use of AspenTech products and provides answers to frequently asked questions.
- AspenTech courseware available in online and in-person versions
- AspenTech business consultants

This guide assumes that the user has Aspen HYSYS V8.6 or higher installed on his or her computer, and has completed a functional process design.



Setting up a Steady-State Compressor Model in Aspen HYSYS

Before beginning the setup for a steady-state compressor in Aspen HYSYS, process components and a fluid package must be selected. This guide assumes that these tasks have already been completed.

Before dynamic simulation can be initialized in Aspen HYSYS, a working steady-state simulation is required. Begin by placing a compressor block onto an Aspen HYSYS flowsheet, and then attach an inlet, outlet and energy stream. In order to have a working steady-state simulation, the inlet stream into the compressor must be fully specified, and either a heat duty into the compressor, the compressor's pressure increase, or the compressor's pressure ratio must be defined. To enter any of the three compressor values, double click the compressor block on the flowsheet, go to the "Parameters" section under the compressor's "Design" tab, and then type a value in the appropriate box. In addition, choose whether the compressor is centrifugal or reciprocating.

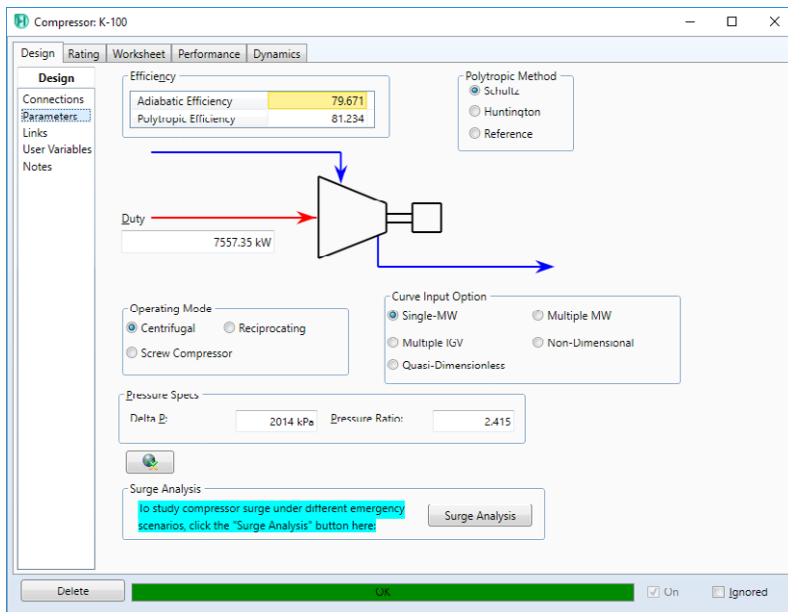


Figure 1:
Parameters section to set up a steady-state compressor model in Aspen HYSYS

Having a converged, steady-state compressor model now enables continuation to dynamic simulation to view how the compressor will respond under disturbance.

Preparing a Dynamic Model From a Steady-State Compressor

In order to model a steady-state compressor dynamically in Aspen HYSYS, the appropriate dynamic control models must be placed onto the flowsheet and set up.

For the purposes of the remainder of this guide, an example process containing a previously solved steady-state compressor will be used. The file **DYN COMPRESSOR MODEL SAMPLE.HSC** came attached to this guide, and should be downloaded and opened in Aspen HYSYS.

Adding and Plotting Compressor Curves

In order to view the dynamic response of the compressor, compressor performance curves must be added to the model. To accomplish this, click the “Rating” tab in the compressor window, and select the “Curves” option in the navigation pane. Enter the operating speed of the compressor, and choose an efficiency type for the curves. Either a linear or quadratic extrapolation method can be used between compressor curve points by choosing the appropriate option in the “Extrapolation” grouping. When finished selecting curve options, check the “Enable Curves” box, and select “Add Curve...”.

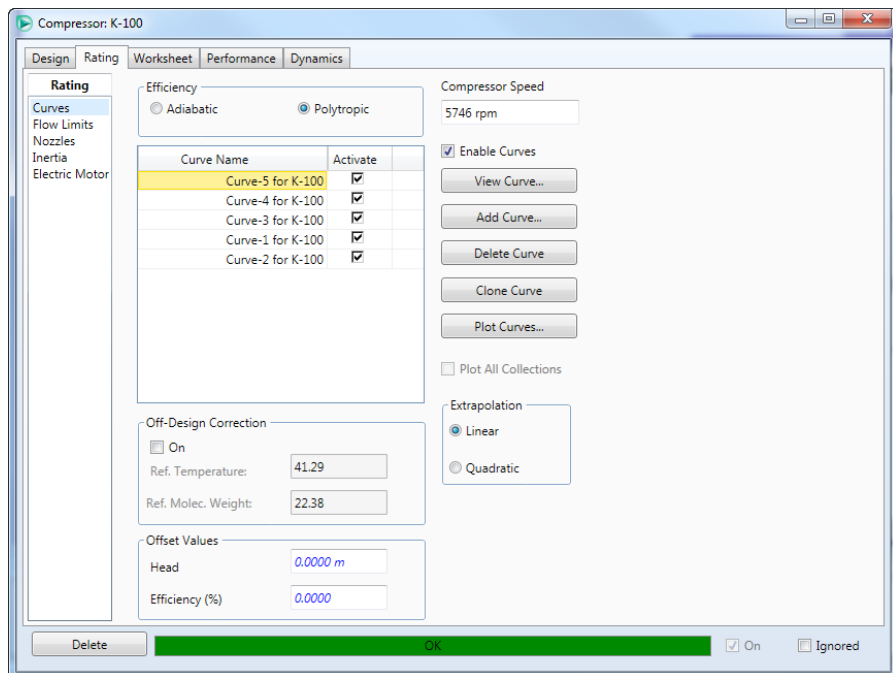


Figure 2:
Setup window for addition of compressor curves, including completed curves

Input the compressor operating data, which is usually obtained from compressor manufacturers. Compressor curves plot the head of the compressor unit versus a volumetric fluid flow at a constant compressor operating rate. The efficiency of the compressor for a volumetric fluid flow can also be defined. Shown in Figure 4 is an example of data for the compressor in the simulation operating at 4900 rpm.

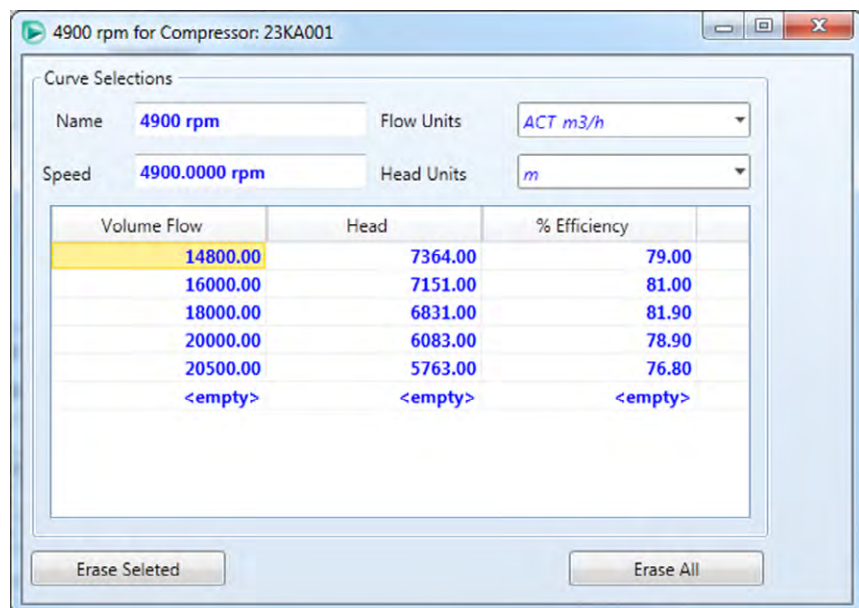


Figure 3:
Window enabling compressor curve addition

After all compressor curve data has been entered and an operating speed for the compressor has been designated, return to the setup window for the compressor curves, and click "Plot Curves...". A plot of the compressor curves for the specified operating rates, as well as the current operating point for the steady-state compressor along the curves will be displayed, and is shown in Figure 5. Additionally, a surge curve is displayed if input by the user. The surge curve shows the boundaries past which the compressor would experience a surge in operation. How to edit the surge curve will be detailed in the following section.

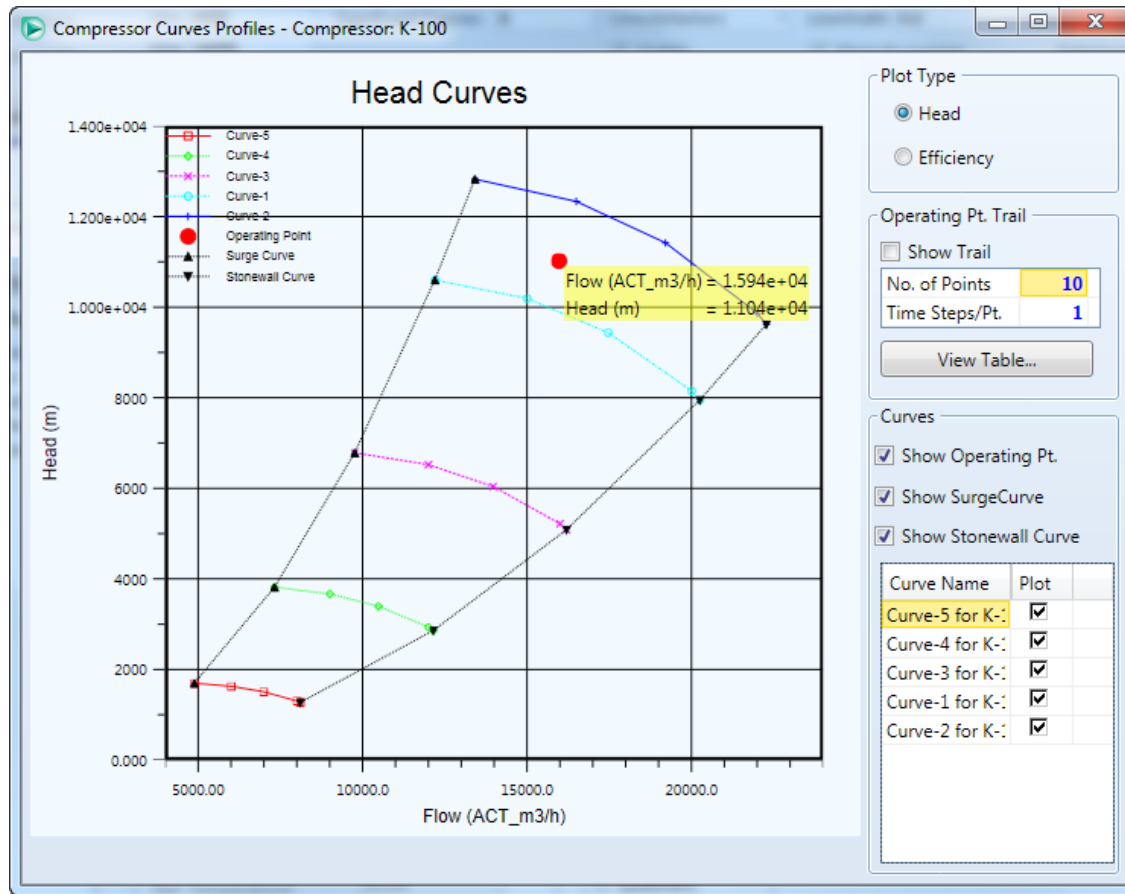


Figure 4:
Compressor curves plot
including surge and
stonewall curves

Note that this plot is a view of head versus flow at various compressor speeds. To view compressor efficiency versus flow, choose the "Efficiency" option under the "Plot Type" grouping in the top right of the compressor plot window.

Modifying the Surge Curve

A surge curve can be seen in Figure 5. This surge curve was previously inserted into the simulation. If beginning a dynamic simulation from a new steady-state simulation, or to edit the surge curve present in the example file, click the “Flow Limits” option in the compressor window navigation pane under the “Rating” tab, as shown in Figure 6. Then, click “Surge Curve...”.

Clicking “Surge Curve...” opens the window shown in Figure 6. The compressor speed and/or the flow at which surge occurs can be edited to either modify existing points or generate new points for the surge curve.

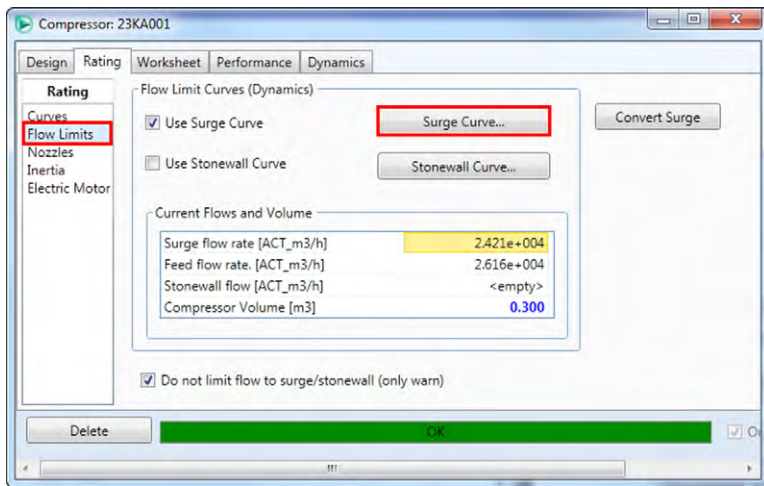


Figure 5: Navigating to edit the surge curve

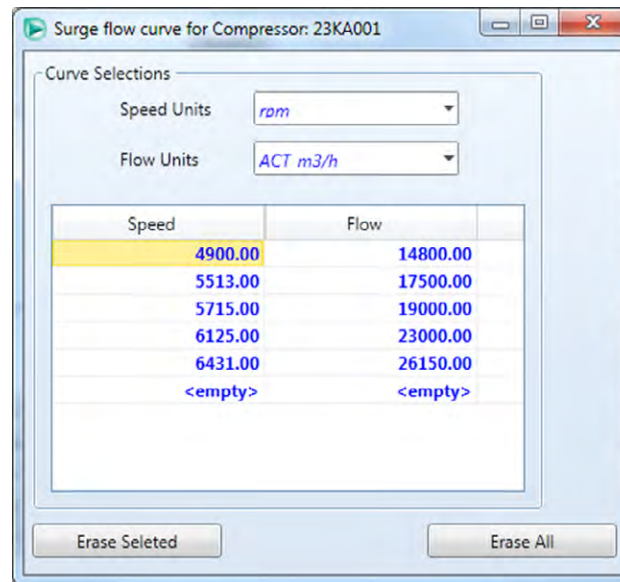


Figure 6: Edit window for surge curve

After ensuring that the compressor and surge curves are properly plotted, continue to the “Inertia” section of the “Rating” tab to update parameters pertaining to the inertia of the compressor impeller and shaft.

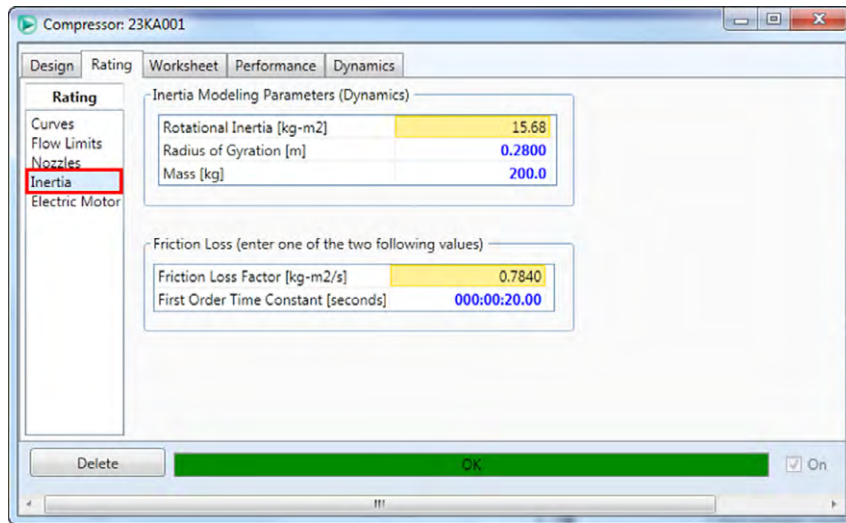


Figure 7: Updating inertia parameters

Finally, continue to the “Dynamics” tab to edit the surge controller. Click “View Surge Controller...”, as shown in Figure 8.

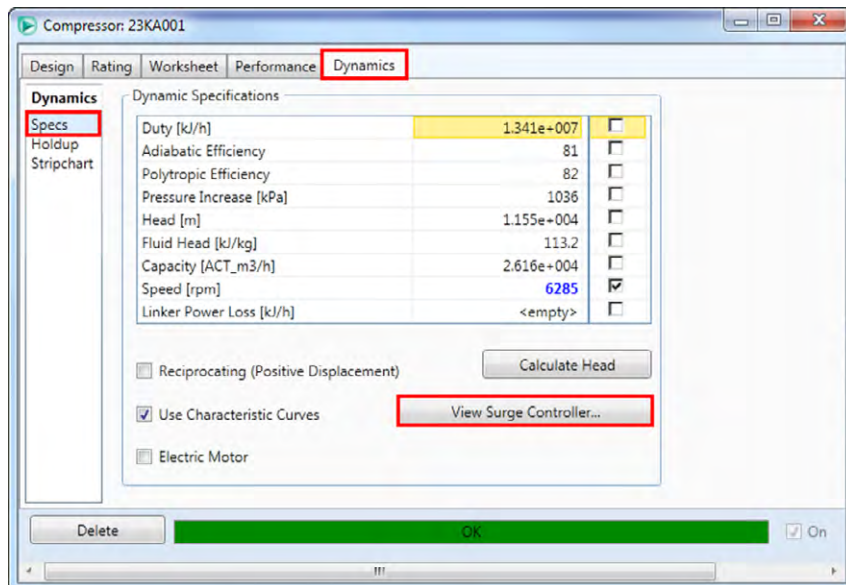


Figure 8: Editing the surge controller

This opens the surge controller window. Verify that the surge controller has the proper connections and objectives, and then navigate to the "Surge Control" option under the "Parameters" tab. Here, the robustness of the surge controller can be managed by varying the surge control parameters.

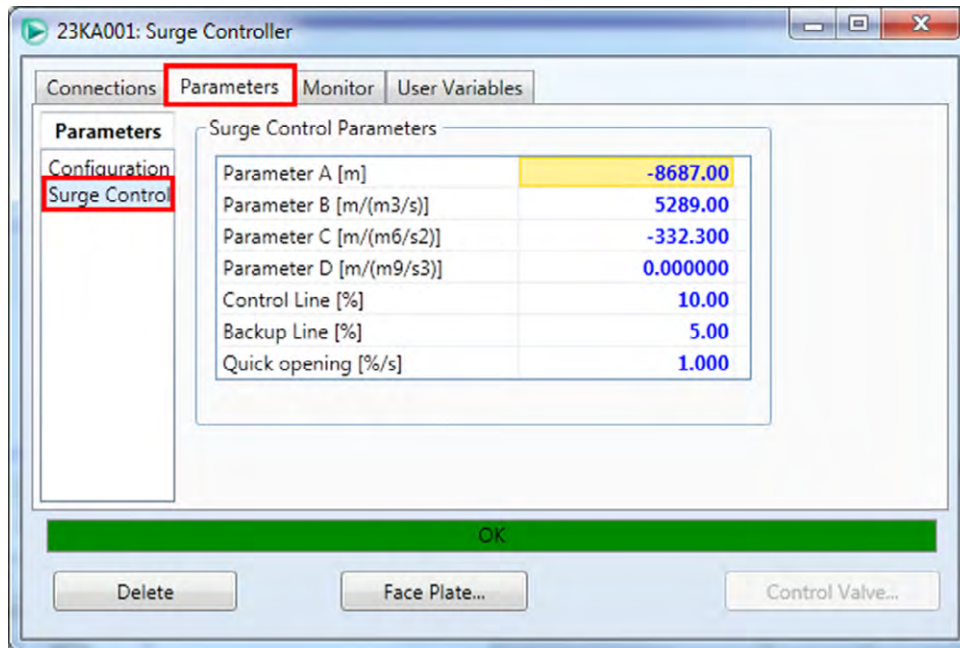


Figure 9:
Modifying surge controller parameters

Dynamic Modeling of Compressor Performance

After all compressor curves have been added, compressor performance can then be examined using Activated Dynamics. Use an example file from the Example File directory, which can be accessed by clicking on the “Example” button in the “Resources” tab directly from Aspen HYSYS. For this section, an example file named **K-100** will be used. This file is located in the Compressor Surge Analysis Folder, along with a number of other compressor surge example files.

After opening the case, on the “Home” tab of the ribbon click on the “Compressor Surge” button in the Analysis group.

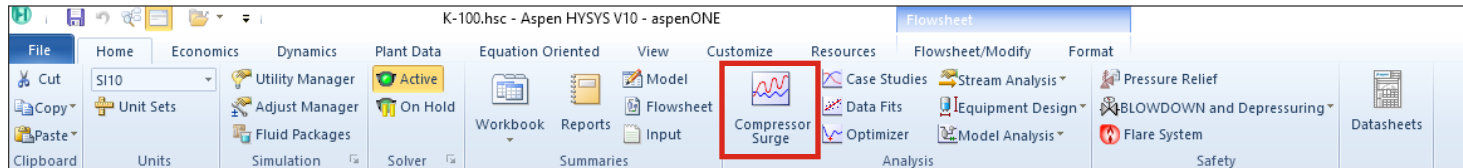


Figure 10: You can create a new dynamic subflowsheet by using the “Compressor Surge” feature under the Analysis group on the “Home” tab of the ribbon.

Select the arrow next to the “Add” button, and, from the drop-down list, select “Dynamic Compressor.” The “Compressor Surge: Dynamics” dialog box appears. On the “Compressor Surge: Dynamics” dialog box, next to the “Unit” field, click the drop-down under “Compressor Name” and select K-100. Then select “Cooler on discharge side, no downstream scrubber” from the “Template” drop-down. Click “Enter Flowsheet” to generate the dynamic subflowsheet.

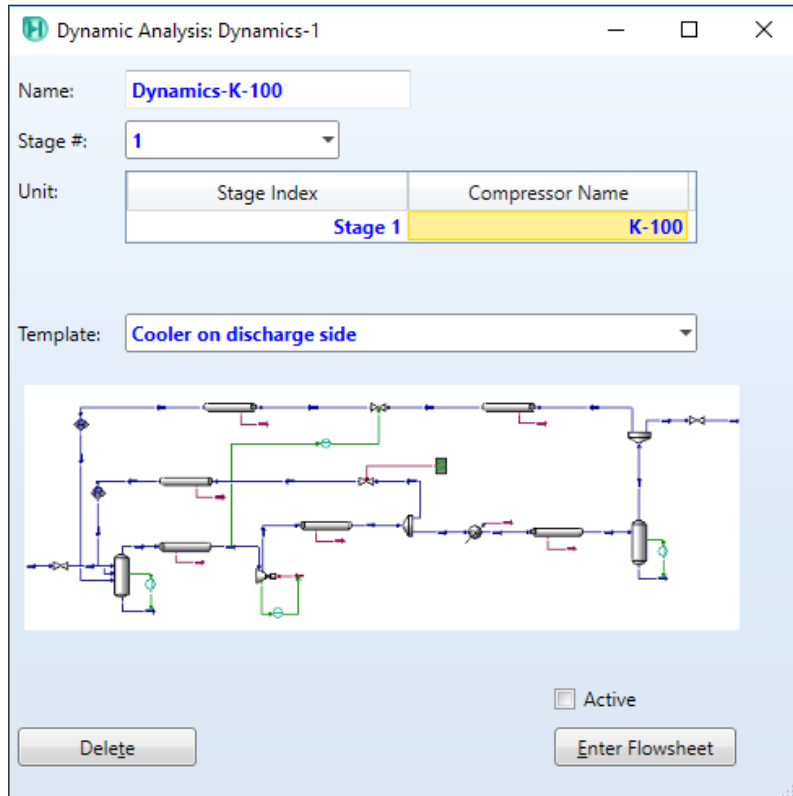


Figure 11: On the Activated Dynamics setup form, you can select how many stages your compressor system has, and which template you would like to use.

The “Cooler on discharge side, no downstream scrubber” template includes two sets of degrees of freedom with a single criterion to pass four scenarios. The first set of degrees of freedom is for the surge controller and anti-surge valve size. The second set is the hot-bypass valve size and overall discharge volume size.

From the ribbon, you can access the “Summary” button on the modified “Dynamics” tab to view and, if necessary, modify the default settings from the Summary view before running scenarios. On the Summary property view, select the “Run Controls” tab. You can view a run time length of 30 minutes (1,800 seconds) and a step size of 50 milliseconds (0.05 seconds).

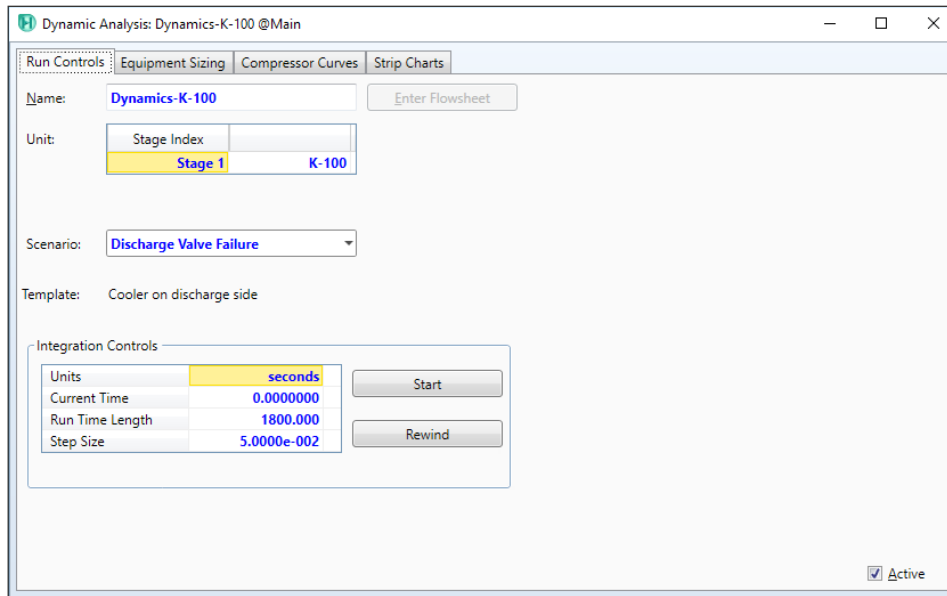


Figure 12:
Summary form Run Controls view

Select the “Compressor Curves” tab. The Compressor Curve Status appears as “Input Complete.” If you select the “Edit Curves” button, the Curves page of the “Rating” tab of the compressor property view appears. The single criterion for success or failure is based on the trail of the compressor operating point in the compressor map that is generated during the particular test scenario. You can also access the Flow Limits page of the “Rating” tab from the compressor property view to verify your selections.

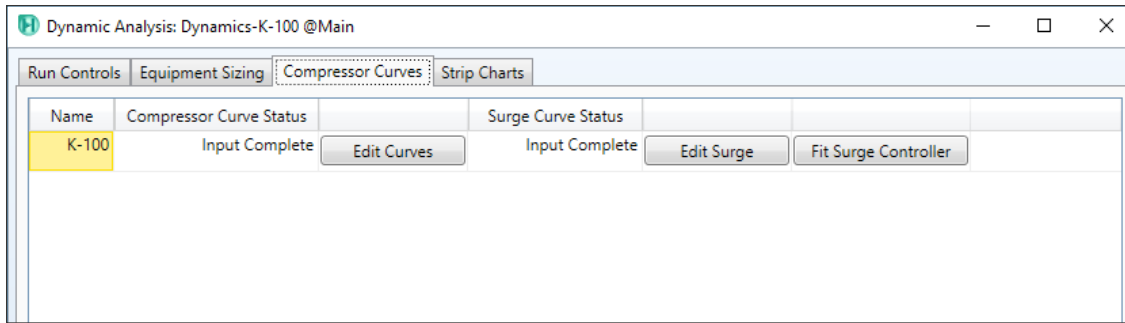


Figure 13: Summary form Compressor Curves view

Select the "Strip Charts" tab of the Summary view. For consistency with the graphical display settings in Figure 1, the settings of the strip charts are 20,000 samples every 100 milliseconds.

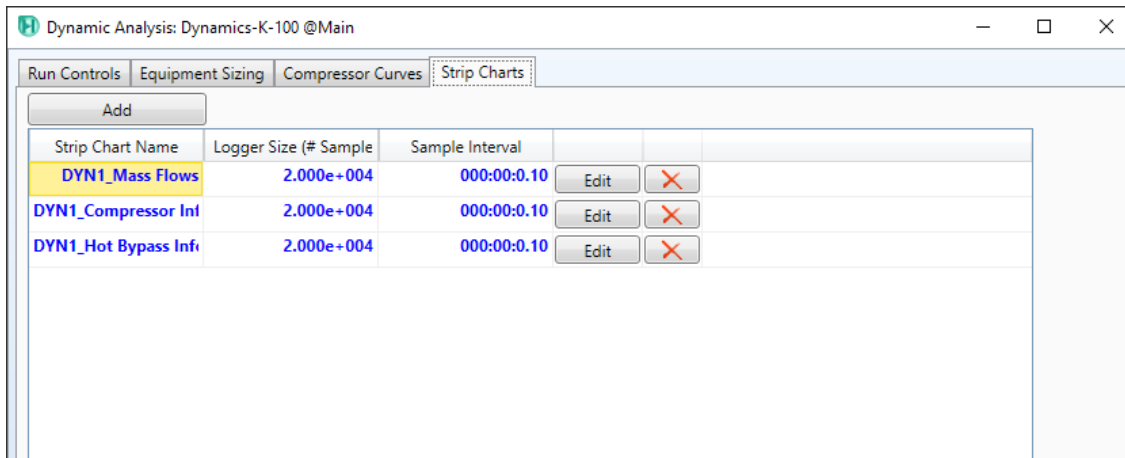


Figure 14: Summary form Strip Charts tab view

To run the Discharge Valve Failure scenario, select “Discharge Valve Failure” from the scenario drop-down list on the “Dynamics” ribbon tab. You can select the “Event Scheduler” button on the “Dynamics” tab of the ribbon to view further details regarding this scenario. On the “Dynamics” ribbon tab, click the “Run” button. Make sure that the “Real Time option” is cleared and observe the scenario results on the strip charts.

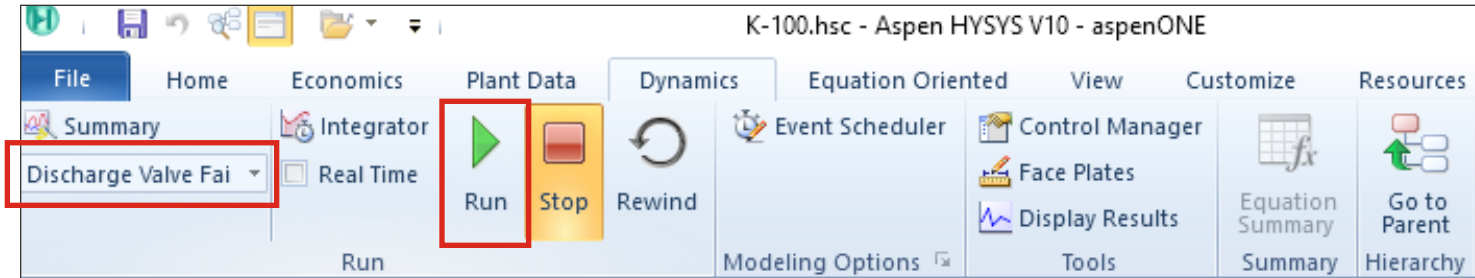


Figure 15: Dynamics tab in Dynamic subflowsheet

This test has passed, since the operation point did not go beyond the surge curve boundary. A real compressor crossing into the surge region, on the left side of the surge curve, is at potential risk of severe damage.

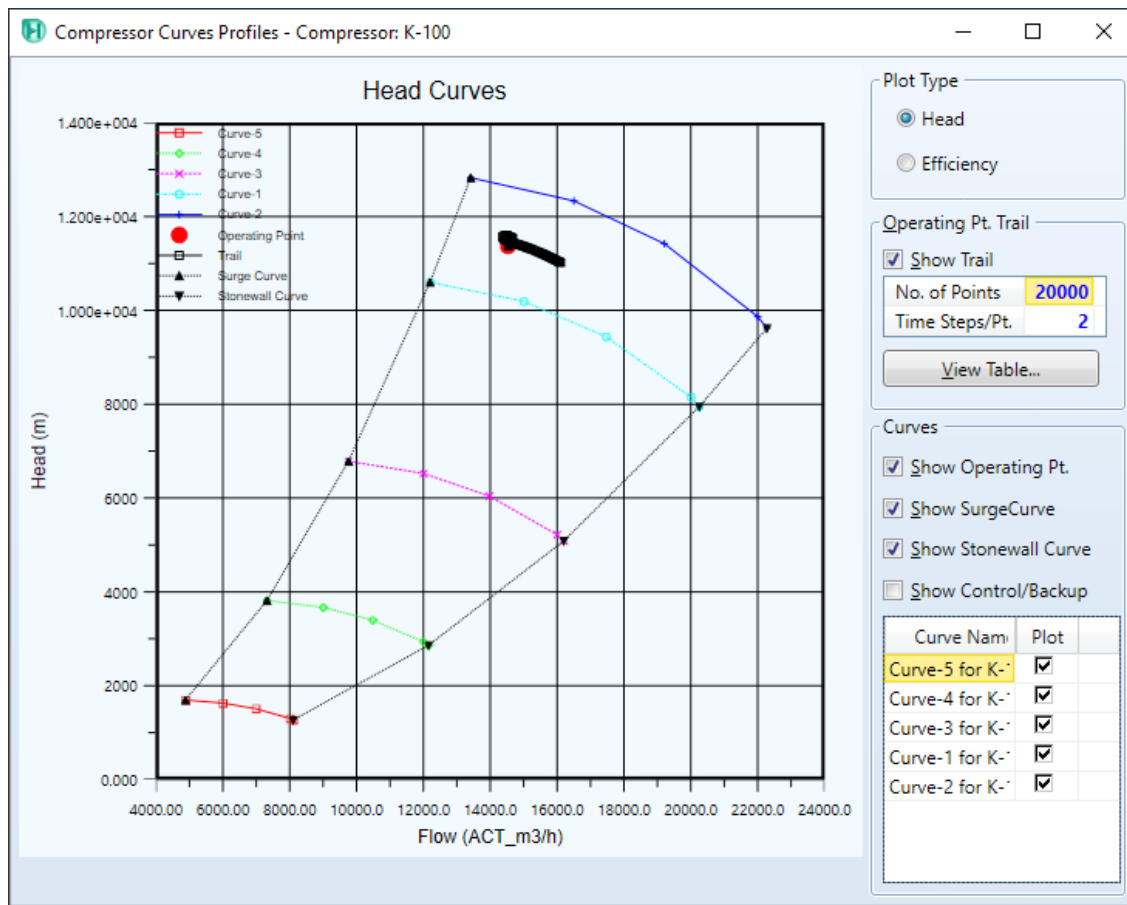


Figure 16:
Discharge valve failure
scenario run results

At this point, you can now rewind the case and run any of the other scenarios available to you. Any changes made before the next run will become the new point the case rewinds to in future cases. To rewind, use the "Rewind" button on the "Dynamics" tab of the ribbon.

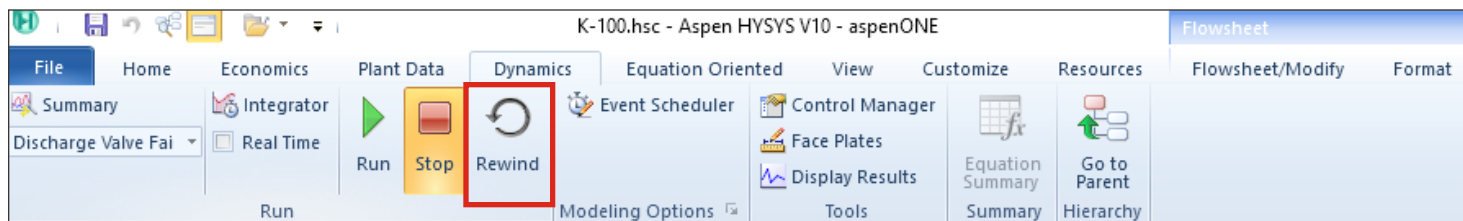


Figure 17: Dynamics ribbon tab, rewind button

Conclusions

Controlling compressor surge is very significant for safe process operation and mitigating equipment malfunction and subsequent replacement. Aspen HYSYS Dynamics helps engineers model the dynamic changes in performance expected for a compressor experiencing a disturbance, as well as the response of a control loop connected to the compressor. Using Aspen HYSYS Dynamics, many scenarios in which steady-state operation is interrupted can be considered and designed for.

Both numerical and graphical dynamic models are generated in Aspen HYSYS Dynamics, which allows for in-depth analysis to be performed on each completed simulation.

In addition to stopping the feed to the compressor, as performed in this guide, other compressor disturbances could be explored in Aspen HYSYS Dynamics. Control schemes and parameters can also be modified, yielding more or less robust compressor control, depending on the user's preference.

Aspen HYSYS Dynamics is a powerful tool that can be utilized to ensure safe and proper functioning of a process's compressors.

AspenTech is a leading software supplier for optimizing asset performance. Our products thrive in complex, industrial environments where it is critical to optimize the asset design, operation and maintenance lifecycle. AspenTech uniquely combines decades of process modeling expertise with machine learning. Our purpose-built software platform automates knowledge work and builds sustainable competitive advantage by delivering high returns over the entire asset lifecycle. As a result, companies in capital-intensive industries can maximize uptime and push the limits of performance, running their assets faster, safer, longer and greener.

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