Compressor Stability - Negative Slope not Required!

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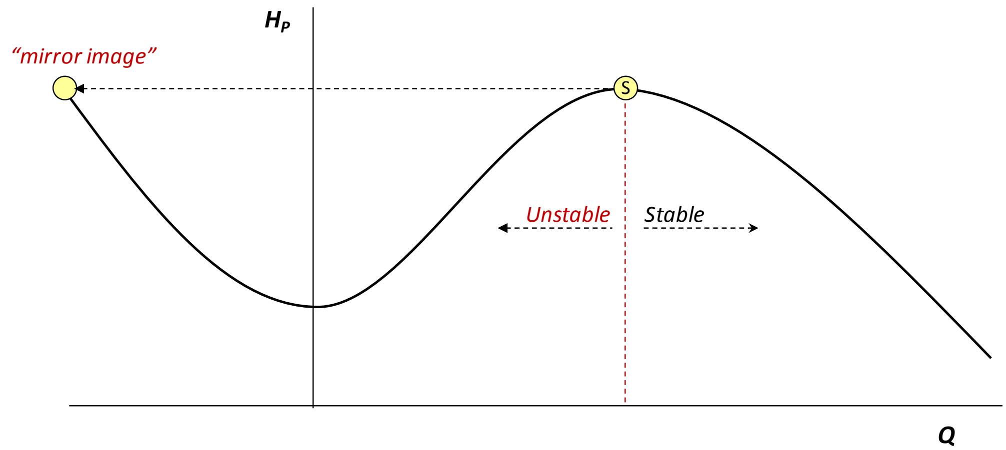
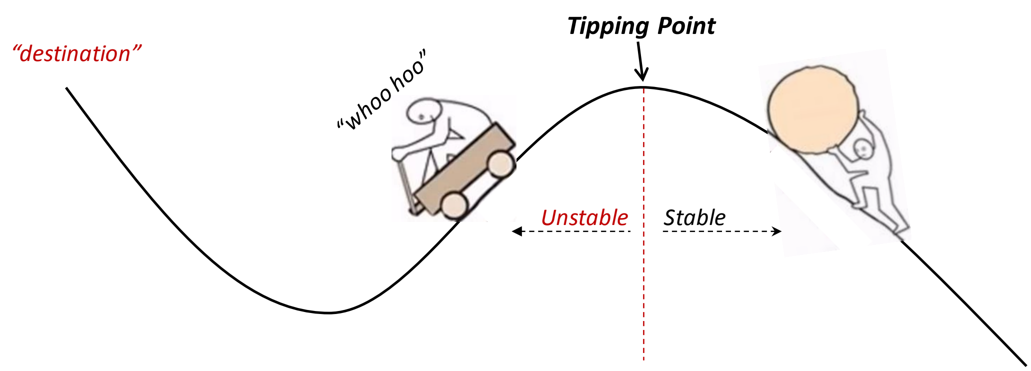
This article examines the effect of performance curve slope on compressor stability. Although a negative slope helps, it isn't required for stable flow control.

A popular view

A popular view is that compressors are stable only in regions where the performance curve slope is negative. Maximum head, where the slope is flat is regarded as the dividing point between stability and instability. That view holds that operating at maximum head can result in a spontaneous transition to its "mirror image" reverse flow.

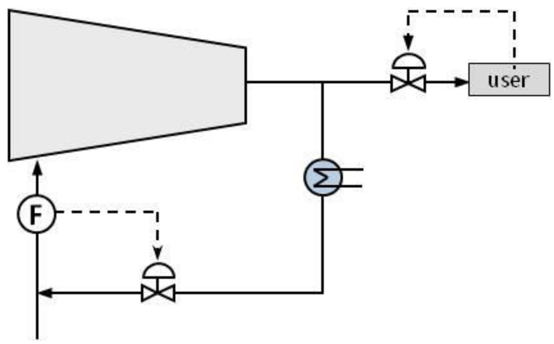


Why is this viewpoint plausible? Why do we accept that the maximum can trigger such a drastic reaction? The answer may be in our familiarity with a tipping point process. Consider the process shown below. Pushing a load up a hill is slow and stable. At the top of the hill the load becomes unstable and can "spontaneously" roll down the other side.



Compressor Stability Analysis

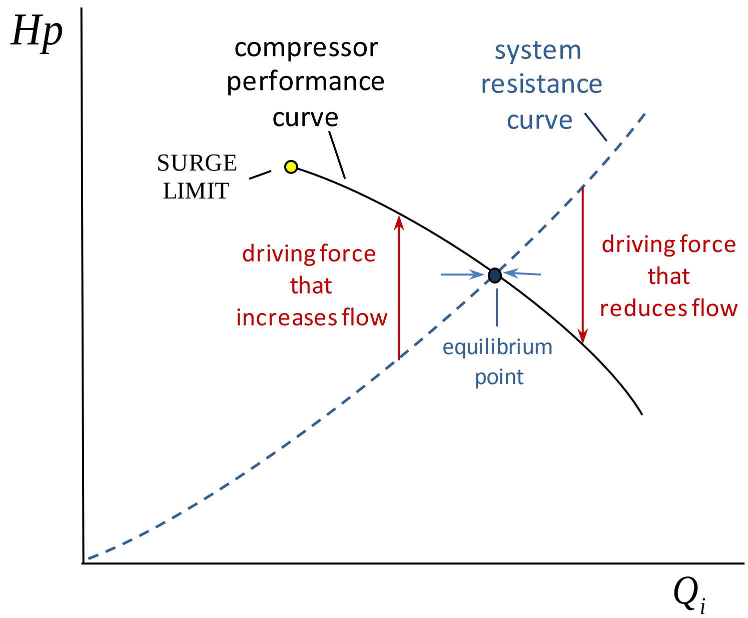
Rather than accepting the tipping point analogy, let's take a closer look at the stability of a compressor system. Consider the compressor system show below. The discharge valve position varies with user demand and the recycle valve is manipulated to control inlet flow rate. We'll look at the effect of three different performance curves on stability.



Typical Performance Curve - Stability

A typical performance curve, which is shown below, has a negative slope throughout the operating range with its minimum flow at surge.   A systems resistance curve has been added in order to analyze the stability of the system. The systems resistance curve represents the pressure drop in the piping, exchanger and valves.

Compressor head and systems resistance interact to drive the flow rate to a point of equilibrium. Where compressor head exceeds system resistance the flow rate will increase. Where resistance exceeds compressor head the flow rate will decrease. The flow rate will settle where the curves are equal.



Process Stability

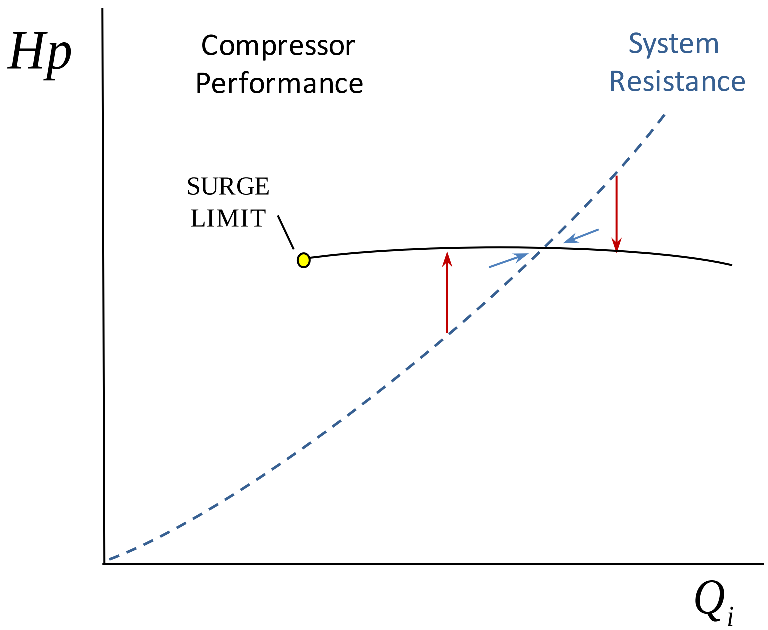
Process stability results from the crossing of the two curves. The greater the difference in slope, the more stable the process.

Volumetric Flow Control

Movement of either valve will rotate the systems resistance curve and shift the equilibrium point. For example, closing the discharge valve will rotate the system resistance curve to the left, thus shifting the equilibrium point to a lower flow rate. A volumetric flow controller would react to the decreased flow rate by opening the recycle valve and shifting the resistance curve back to its original position.

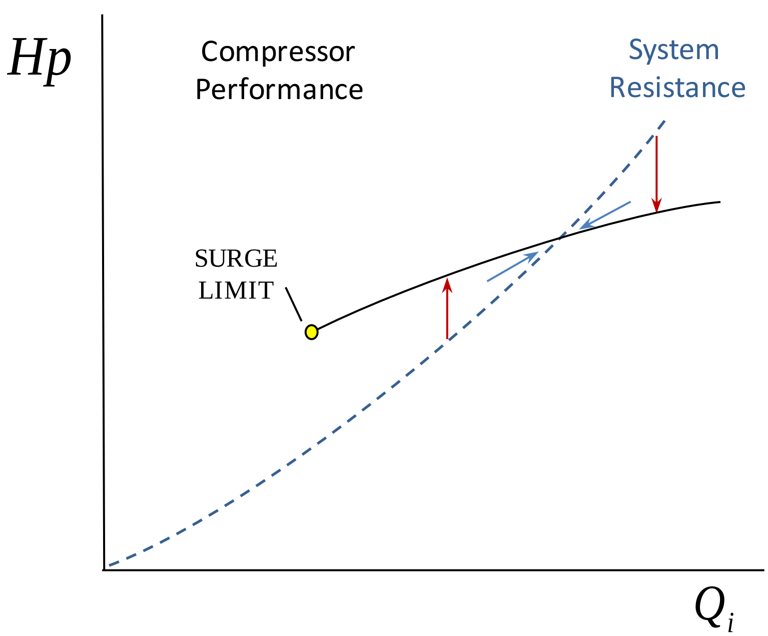
Flat Curve - Stability

Radial impellers result in a performance curve that has "flat" section within its normal operating range. Compared to the previous example, the angle between the system resistance and performance curve is smaller making it less stable, however there is enough difference to provide stable performance.



Positive Slope Curve - Stability

The least stable situation would result from a forward leaning impeller which further reduces the angle between systems resistance and performance. However, even with this reduction the process will be stable as long as the curves cross.



Conclusions

Compressor stability is determined by the differences in slope between the compressor performance and system resistance curves. A negative sloping performance curve adds stability but isn't required for stable operations.

With the necessary piping and instrumentation, a properly tuned inlet volumetric flow controller can provide stable operations regardless of the slope of the performance curve.

This is the third in a series of posts leading to methods for optimizing compressor performance.

Links to Articles in this series:

Compressor Performance - What shapes the curve
Why Compressors Surge - Exposing the real Culprit
Compressor Stability – No negative slope required!
Volumetric Surge Control - A better solution

References:

1. *Compressor Handbook* . Ed. Paul C. Hanlon. New York: McGraw-Hill, 2001. Print.

2. Moore, R. (2016). *Compressor Performance* - *What shapes the curve.* Retrieved from https://simsready.com/posts/Compressor-Performance--What-Shapes-the-Curve.pdf

3. Moore, R. (2016). *Why Compressors Surge* - *Exposing the real culprit.* Retrieved from https://simsready.com/posts/Why-Compressors-Surge--Exposing-the-real-Culprit.pdf