Shifting the Surge Line: How system volume changes stability limits in centrifugal compressors

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Abstract:

Surge is a global instability that limits the stable operating range of centrifugal compressors at low mass flow rates. It is a common belief that the surge inception takes place directly at the maximum point of the compressor performance curve. The aim of this study is to predict the stability limit of centrifugal compression systems and to examine how far stable operation can be extended into the positive-slope region of the compressor characteristic.

The dynamic behaviour of the system is described using the Greitzer model, which introduces a non-dimensional B parameter that characterizes the interaction between the compressor and the surrounding system. A stability boundary expressed as $B_{cr}(\phi)$ was proposed, showing that the critical value of the B parameter varies with mass flow rate and defines the limit between stable and unstable operation. This approach allows the surge inception point to be estimated along the compressor characteristic and provides a practical interpretation that stable operation may continue beyond the maximum point of the performance curve. The results indicate that reducing the downstream volume increases the surge frequency and shifts the onset of instability toward lower mass flow rates, extending the stable operating range beyond the conventional surge line.

Keywords: *Centrifugal compressor; surge phenomenon; Greitzer model; compressor modeling; flow instability; limit cycle.*

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