The Hurst Exponent as a Compressor Surge Criterion

Bertrand Kerres

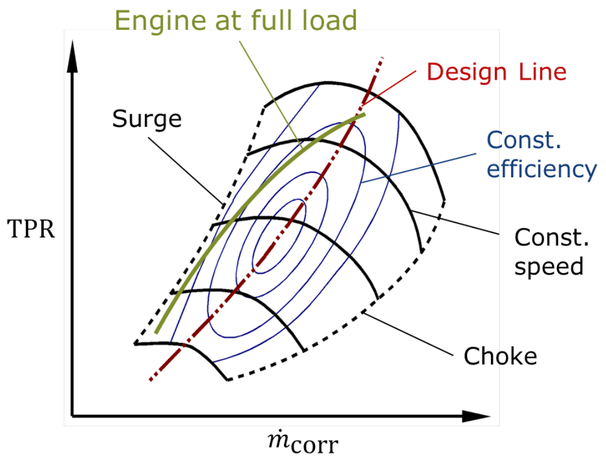
KTH CCGEx

kerres@kth.se

The aim of this project is to investigate the Hurst exponent as a new criterion for compressor surge. It is based on the fractal properties of an underlying time series, e.g. a compressor pressure measurement signal. Investigations show that the Hurst exponent has potential as a surge indicator. The advantages compared to other signal characteristics like the standard deviation are that it decreases from 0.5 for pure white noise to 0 for noise-free oscillations, and that the method can easily be generalized.

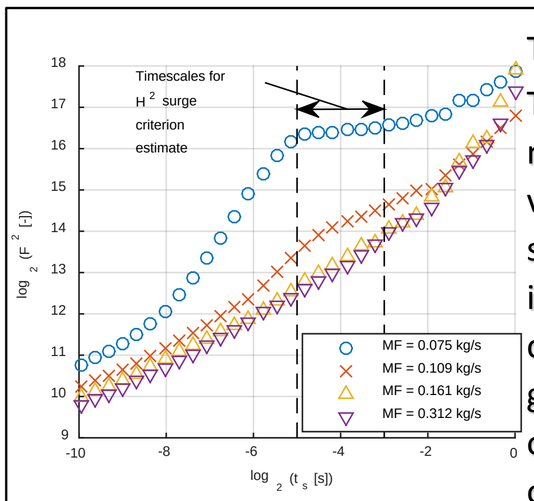
Compressor Surge

Compressor surge narrows the operational range of turbo-compressors at low mass flows. In surge, the compressor can no longer supply a steady outlet pressure to overcome downstream flow resistances, and pressure and mass flow start oscillating.



On turbocharged internal combustion engines, turbocharger compressor operation needs to incorporate a safety margin towards its surge line. This limits the engine low-end torque.

The Hurst Exponent



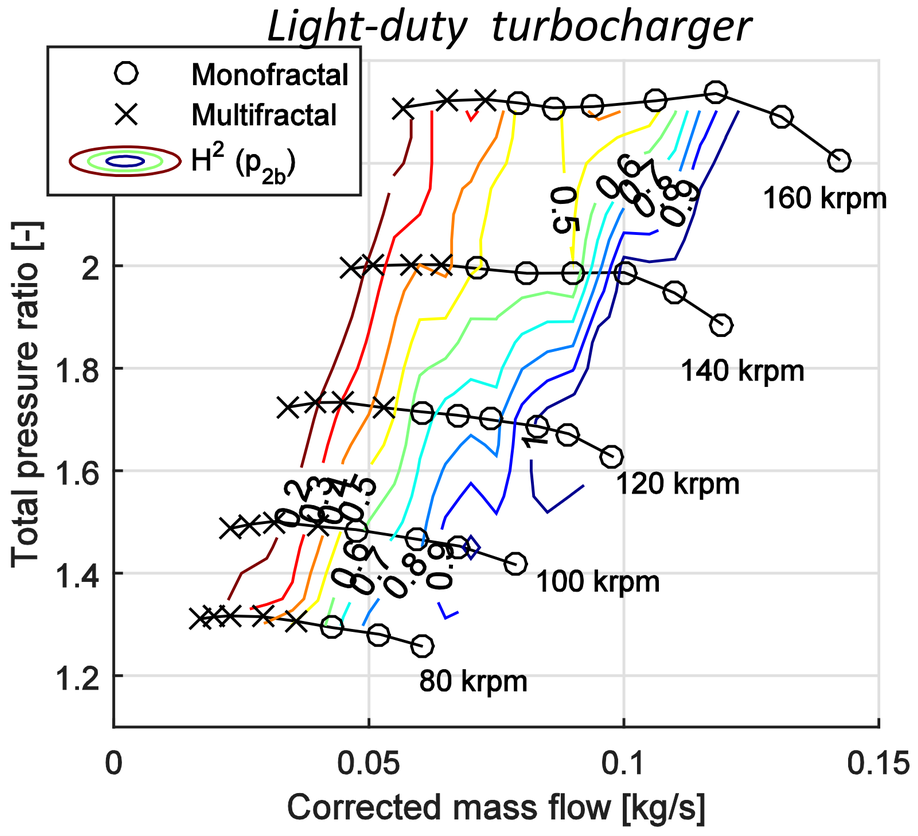
The Hurst exponent is estimated by plotting the average window variance over window length in a log-log diagram. It corresponds to the slope of the resulting lines. Here shown for several mass flows at one impeller speed.

The Hurst exponent (H^2) is a number that describes how the variance of a signal scales with the signal length. Applied to a pressure in the compression system, one can expect a scaling behaviour governed by turbulence for stable operation. For near surge operation, on the other hand, the pressure is wave-like and the signal variance becomes almost independent of the its length. One can then expect the Hurst exponent to move towards zero.

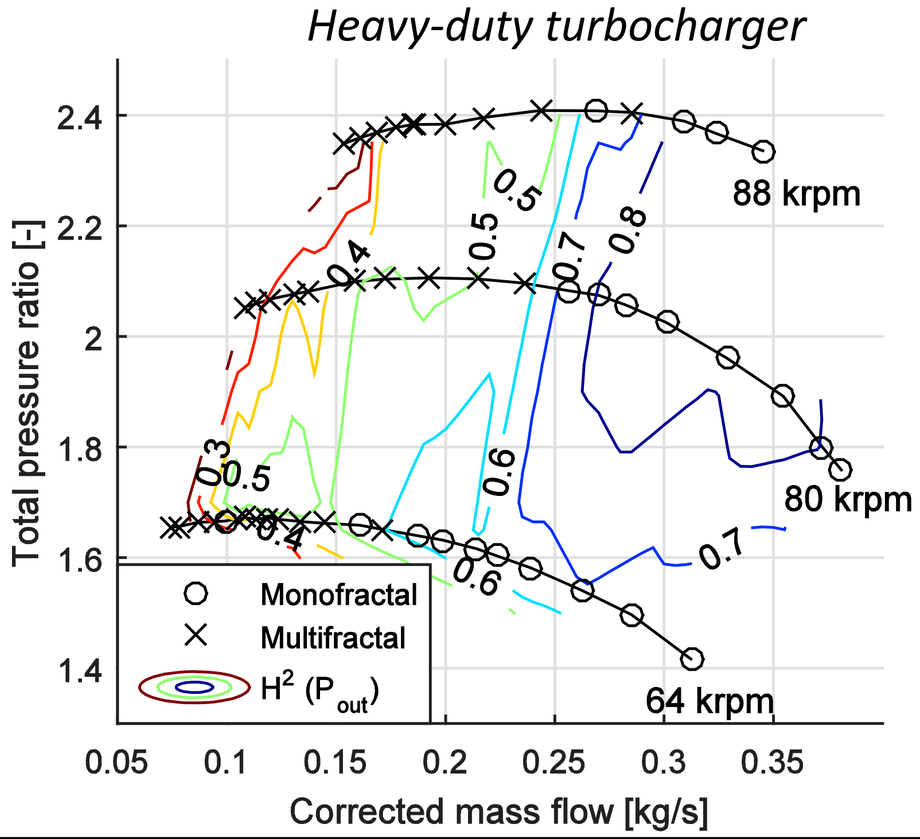
Results

Compressor maps for a passenger car sized (left) and a truck sized (right) turbocharger show a decrease of the Hurst exponent H^2 towards surge, with a limit before deep surge at around $H^2 = 0.15$. An additional criterion that distinguishes between monofractality (large and small amplitude oscillations scale equally) and multifractality (large and small amplitude oscillations scale differently) of the pressure signal at surge time scales could have some potential as an early warning indicator.

Light-duty turbocharger



Heavy-duty turbocharger



Summary and Conclusion:

Main advantages of the Hurst exponent as a surge indicator are its well-defined limit of zero for pure oscillations, and the flexibility due to the different orders and different signal detrending options. The main drawback compared to e.g. the power spectrum is the complexity of the underlying concept.

Acknowledgement:

Supervisors: Andreas Cronhjort, Mihai Mihaescu

SCANIA VOLVO VOLVO Energimyndigheten BorgWarner