Current experimental compressor investigations – a short overview

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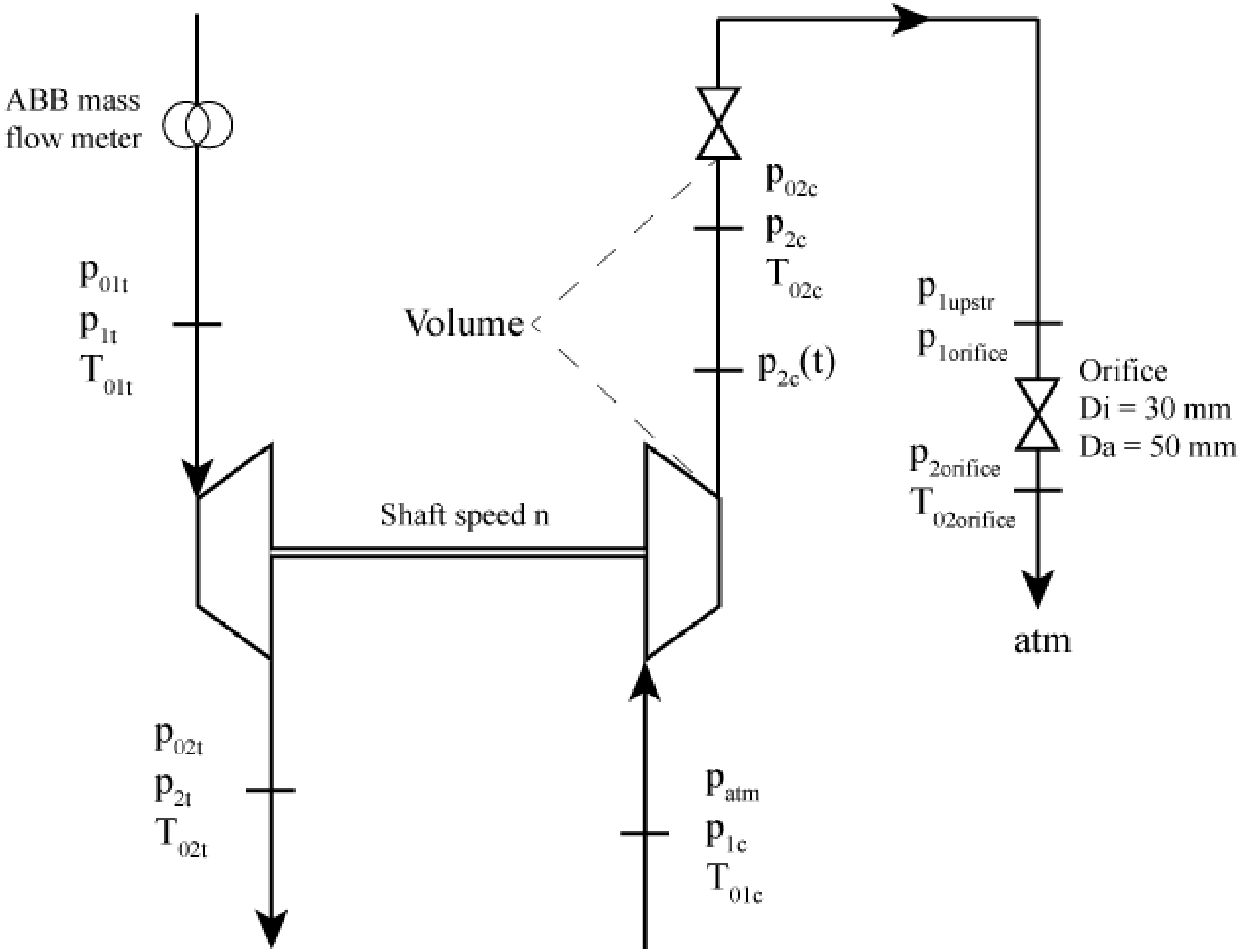
Research questions

- Hurst exponent as a criterion for compressor surge
- Effect of bended inlet on compressor performance at low mass flows
- Impeller flow recirculation

Experimental setup

- GT1752 turbocharger (6+6 blades, TRIM = 0.53)
- Cold gas stand
- Orifice for mass flow measurements (accurate, but no oscillations)
- Relatively small volume between compressor and throttle (approx. 1 L)

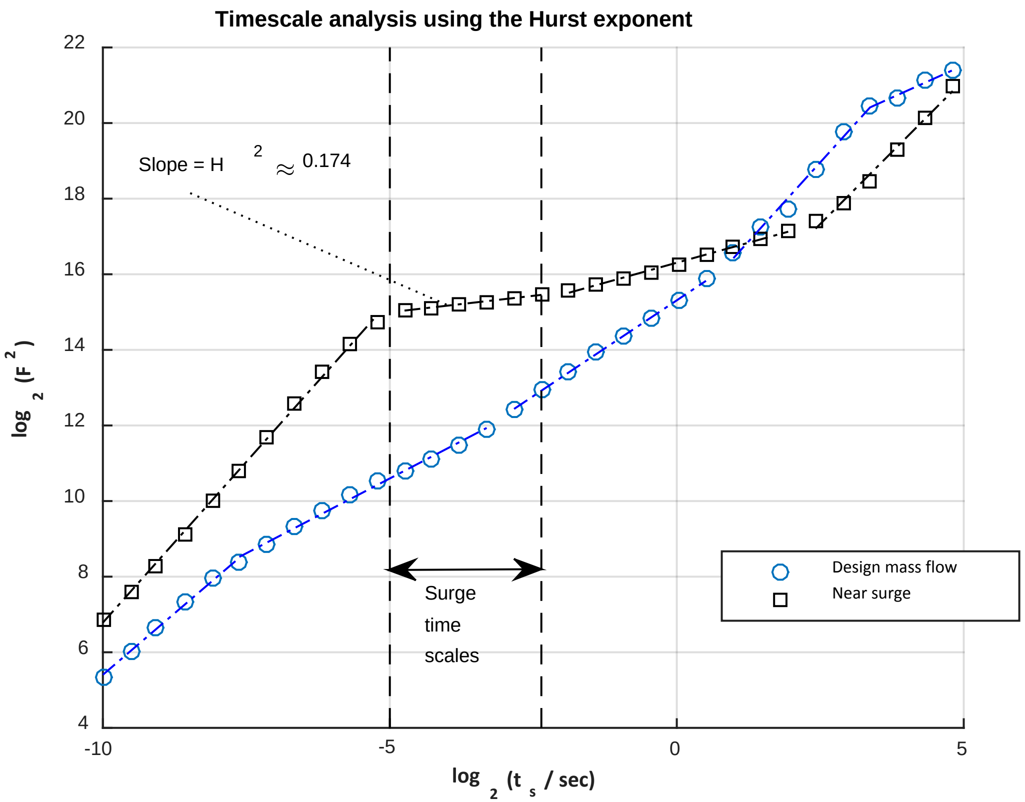


The Hurst exponent as an indicator of compressor surge

- Hurst exponent H^2: non-dimensional number that gives information about correlations and long-term trends in a time series

- $H^2 = 0 \ldots 0.5$: Negatively correlated
- $H^2 = 0.5$: White noise
- $H^2 = 0.5 \ldots 1$: Positively correlated
- $H^2 > 1$: Non-stationary

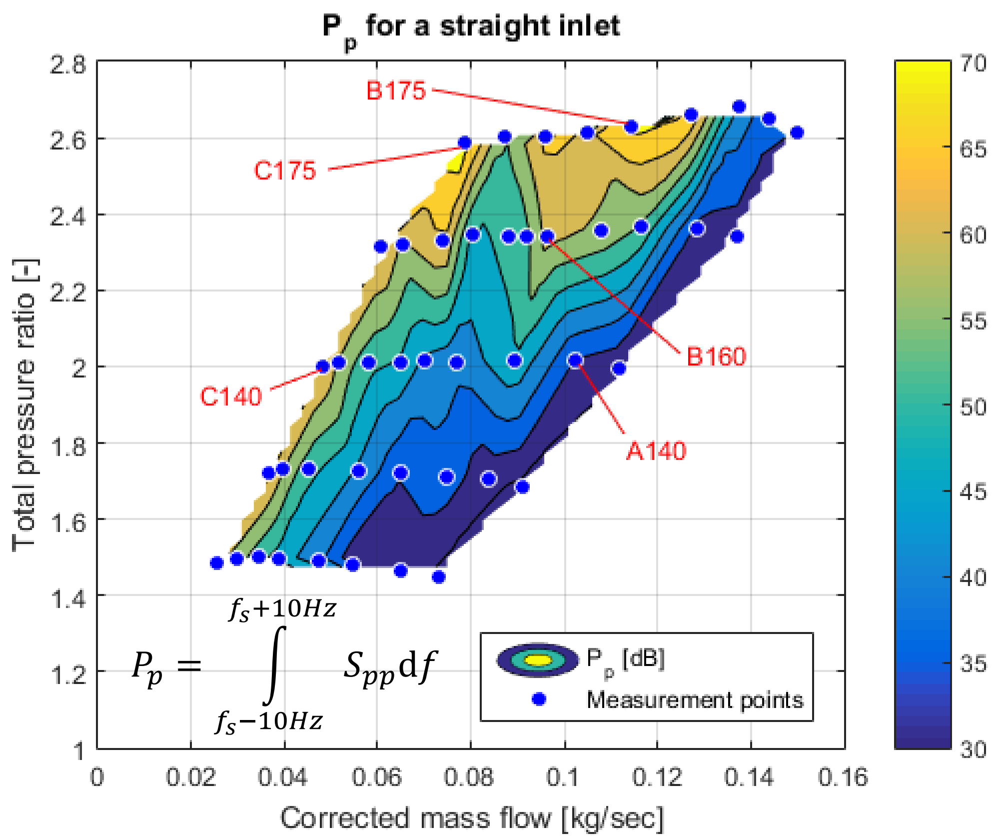
- Compressor surge pressure signal is anti-correlated in the surge time scales → $H^2 \approx 0$

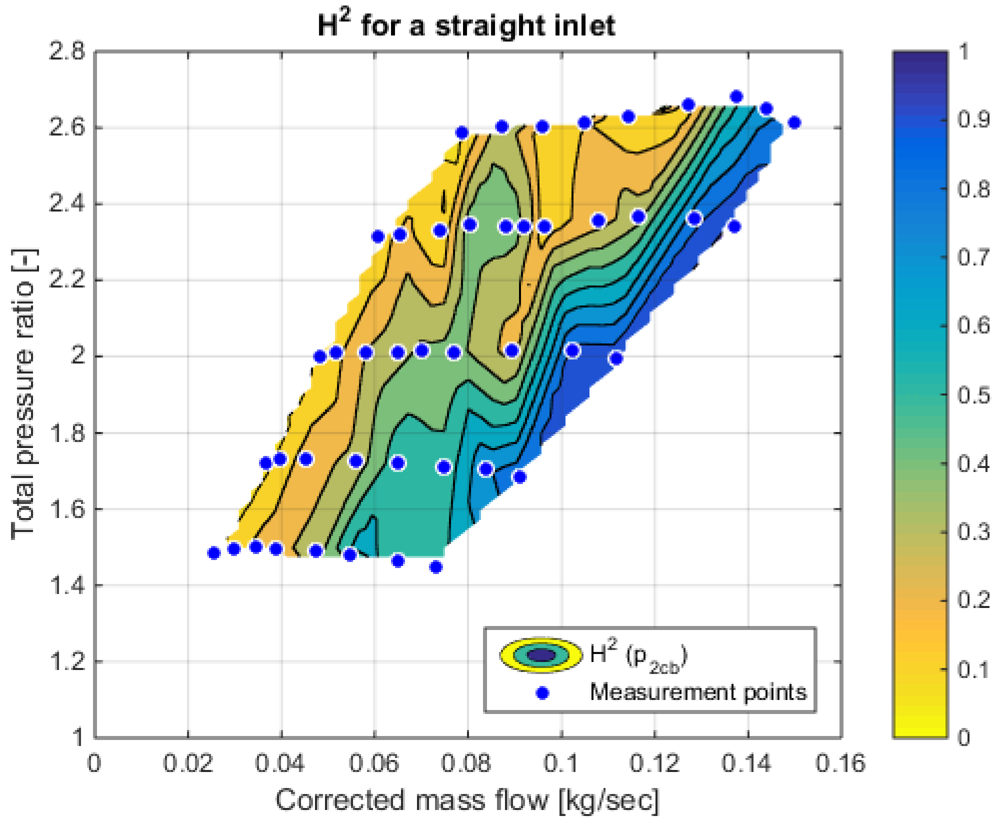


Kerres, B., Kabral, R., Nair, V., and Åbom, M., The Hurst Exponent as and Indicator of Turbocharger Compressor Surge, manuscript in preparation (ASME J Turbomachinery)

Kerres, B., Nair, V., Cronhjort, A., and Mihaescu, M., Analysis of the Turbocharger Compressor Surge Margin Using a Hurst-Exponent-based Criterion, submitted to SAE world congress 2016

Comparison: Spectral Power vs H^2 for Straight Inlet





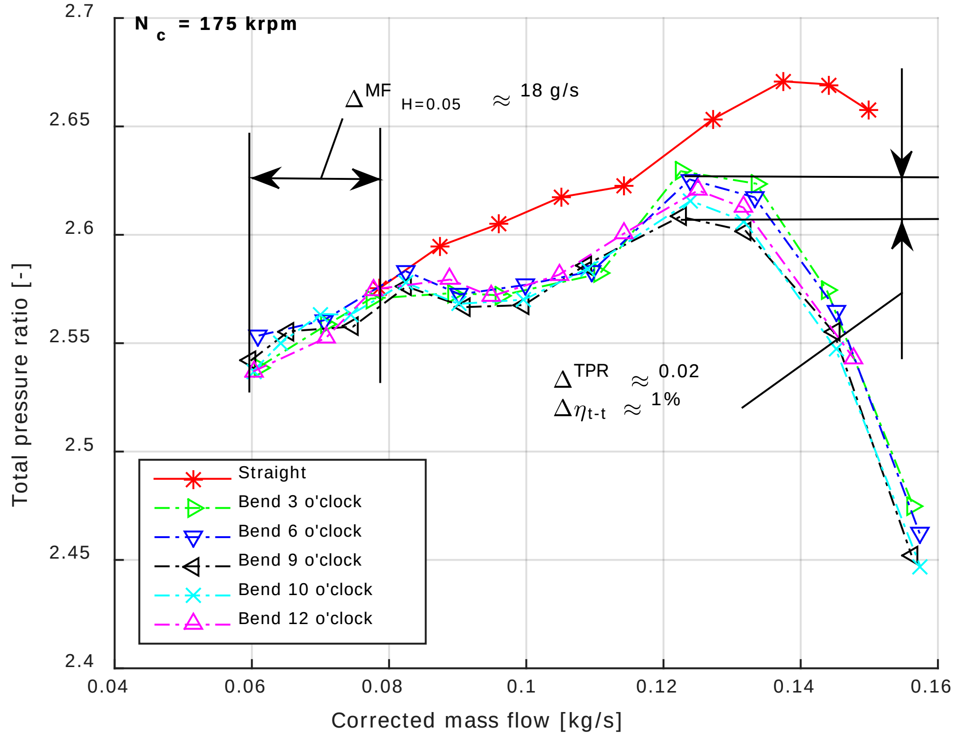
+H^2 has a clear limit for surge, which is system-independent ($H^2 \rightarrow 0$)

+H^2 is more sensitive to small amplitude oscillations → could be better for detection of surge pre-cursors

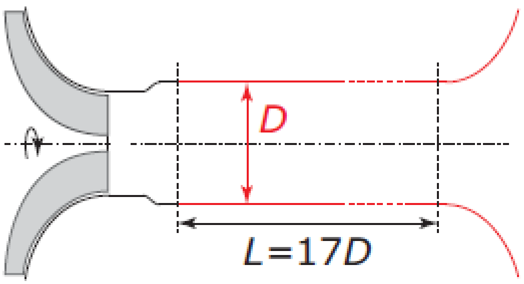
-H^2 is computationally (much) more expensive

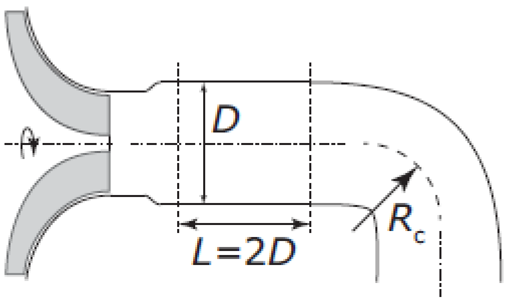
Effect of bended inlet on compressor performance

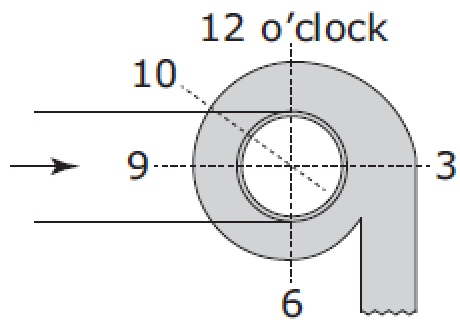
- Inlet geometries:
  - Straight
  - Bend (different orientations)
- Results:
  - Lower pressure ratio (TPR) due to bend losses
  - Bend gives an increase in surge margin at high impeller speeds (value depends on surge threshold)
  - Orientation sligtly affects TPR



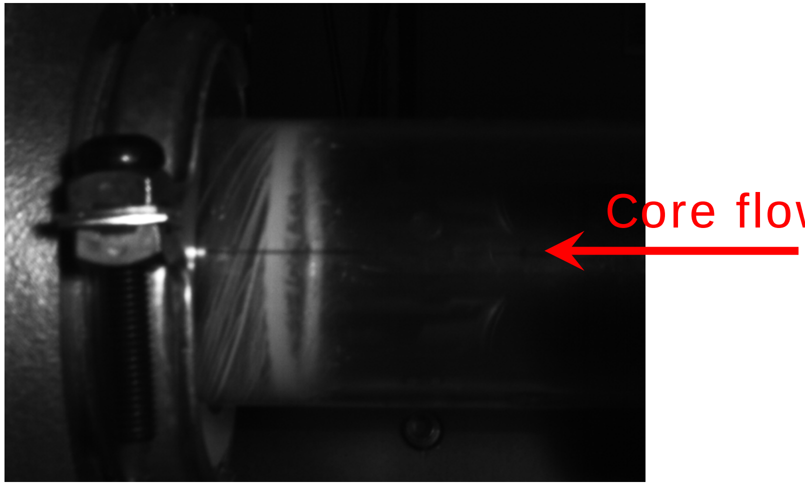
Kerres, B., Cronhjort, A., and Mihaescu, M., Experimental investigation of upstream installation effects on the turbocharger compressor map, submitted to IMechE 12th conference on Turbochargers and Turbocharging

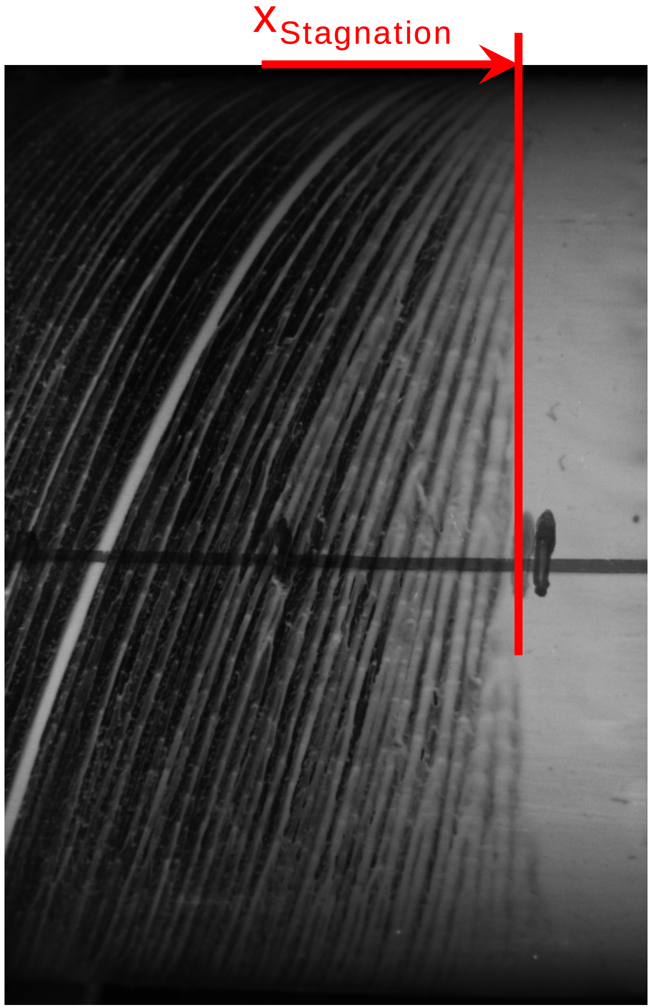






Impeller flow recirculation





- Visualize wall streamlines from the impeller backflow using Zinkoxide + oil
- Experimental data can be used to validate CFD simulations (and evtl. inlet blockage models)
- Flow angle of the backflow can be estimated
- Gain understanding of the flow field if there is an angle upstream

Outlook

- Impeller flow recirculation

- Switch to BorgWarner compressor (start of 2016)
  - Inlet geometry tests
  - Rotating stall detection using pressure transducers (diff. circumferential / radial positions)

- Engine tests

Thank You!

Estimating the Hurst Exponent Using Detrended Fluctuation Analysis

- Here: artificial sample signals x(t)

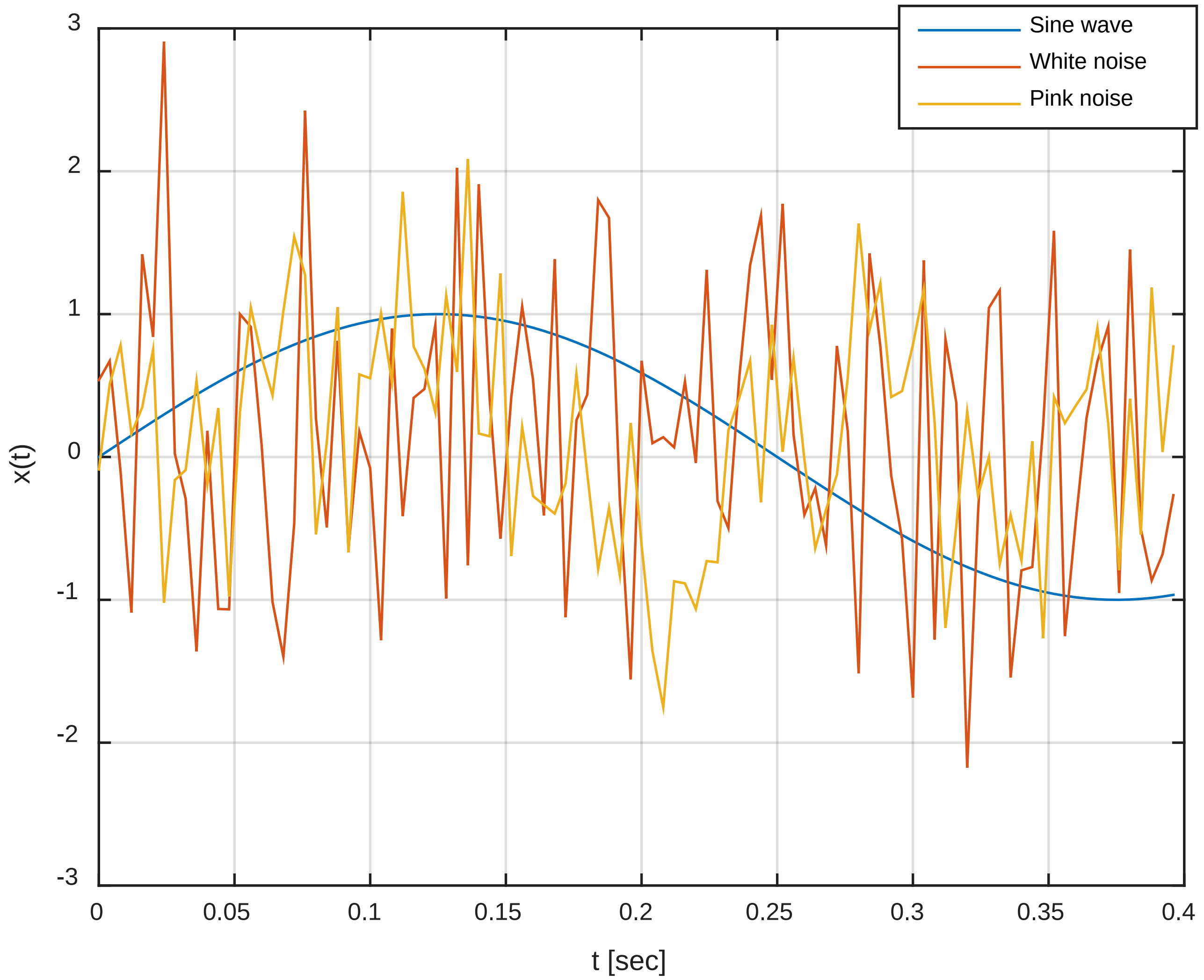
  Sine wave (signal power S contained in 1 frequency):

  $$x_s = \sin(\omega t)$$

  White noise (signal power S independent of frequency):

  $$x_w \sim \mathcal{N}(0,1)$$

  Pink noise (signal power S ~ 1/f)



Estimating the Hurst Exponent

- Using Detrended Fluctuation Analysis (DFA)
- (Simplified) method:
  1. Calculate cumulative series

     $$Y = \sum x_i$$

  2. For different time scales t_s:

     Split into windows with length t_s

     Remove window linear trend

     Calculate window variance

     Calculate root mean of window variances (thus H²)
  3. Plot log-log diagram t_s – root mean (Y)
  4. Fit a linear trend → Slope is the Hurst exponent