Competence Center for Gas Exchange

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”Charging for the future”

Energimyndigheten SCANIA VOLVO VOLVO BorgWarner

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Detecting compressor surge using the Hurst exponent

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Topics

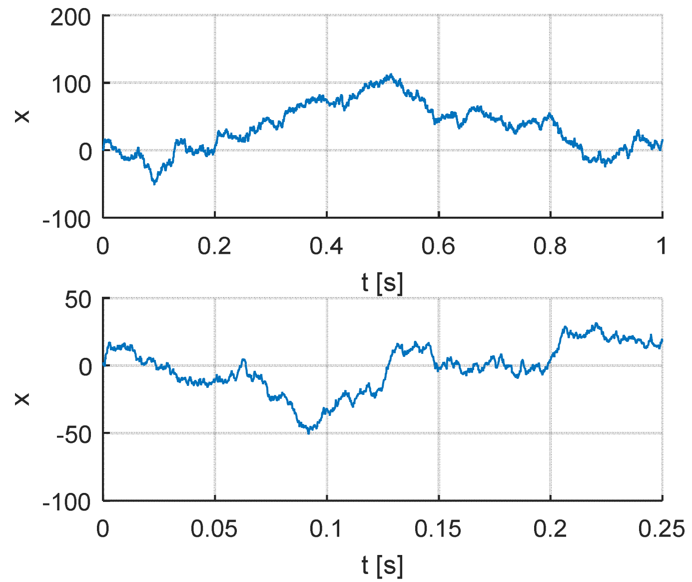
- Investigate the Hurst exponent as compressor surge indicator:
  - General applicability
  - Sensor location
- Algorithm for early detection based on different orders of the Hurst exponent

What is the Hurst exponent

- Hurst exponent H gives information about the scaling and long-term trends for self-similar data

$$x(t) \rightarrow a^H x(at)$$

- Idea: random walk based on pressure data
  - At stable operation, depends on sampling length due to e.g. noise, turbulence
  - Near surge, independent of sampling length since the pattern repeats itself



Ex.: Random walk with step size ~N(0,1) → H=0.5

(see rescaled data axis)

Multifractality – a generalized Hurst exponent

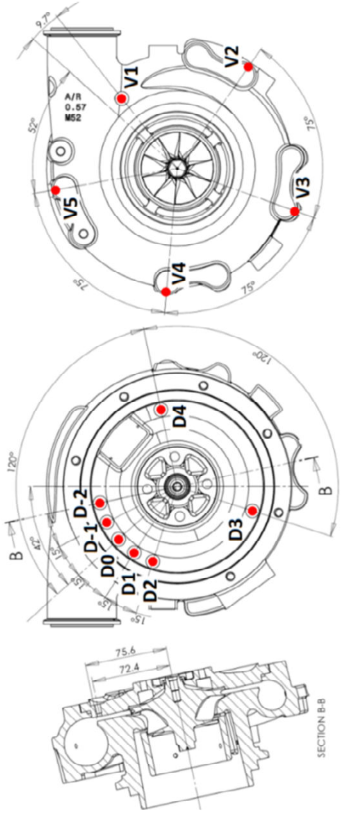
- Hurst exponent of different orders $q \in \mathbb{R}$

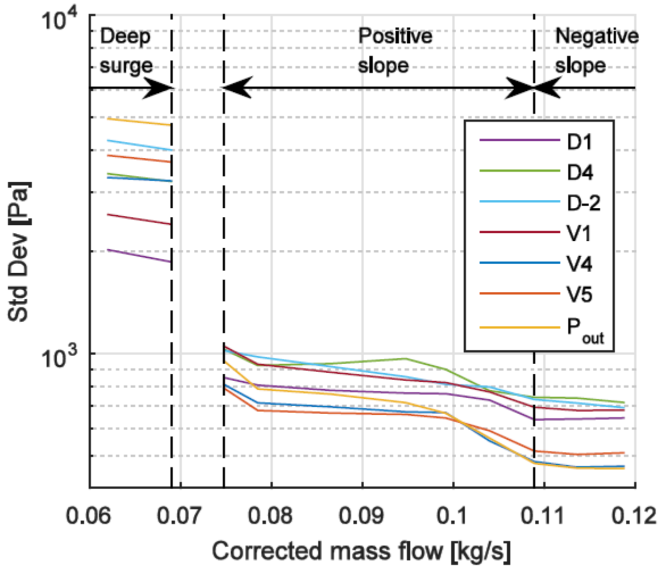
- Monofractality: scaling law is the same for large and small amplitude oscillations
$$H^q \neq f(q)$$

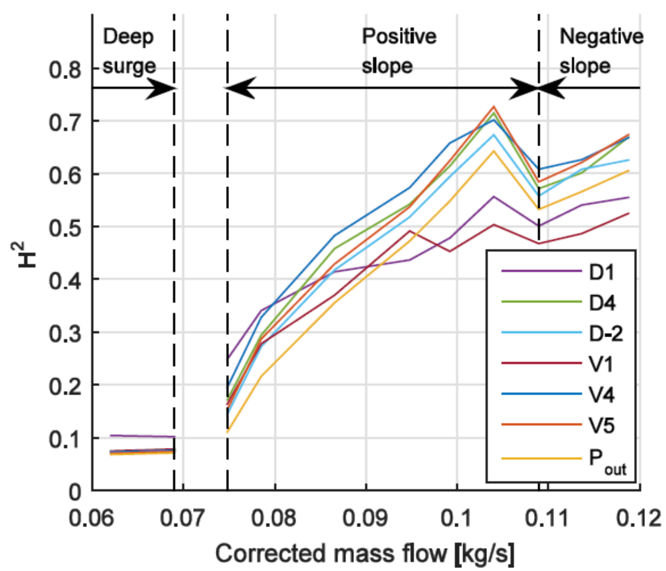
- Multifractality: scaling laws for large and small amplitude oscillations differ
$$H^q = f(q)$$

Results: Hurst exponent vs Std Deviation

(c) E. Guillou (2011)

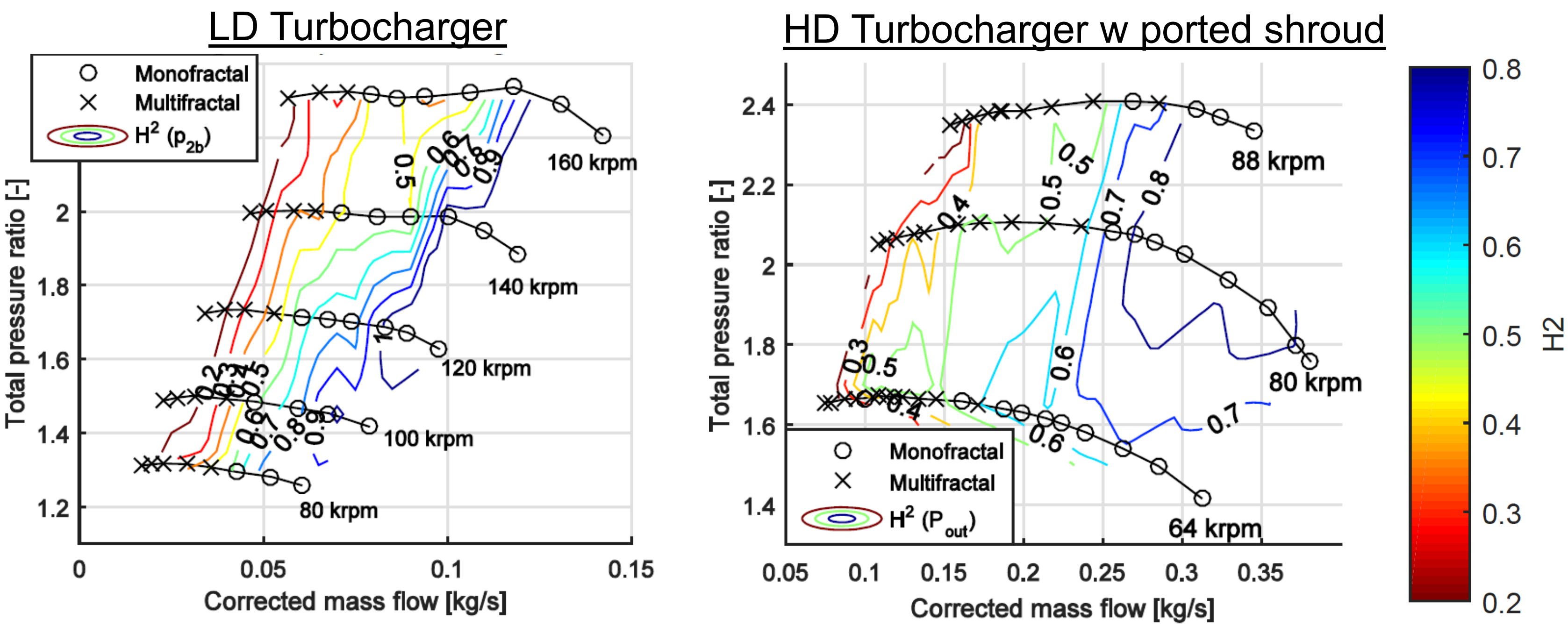






- Honeywell GT40 (HD turbocharger, ported shroud), N=64 krpm:
  - Hurst exponent has better properties as warning indicator
  - Sensors near the outlet and upstream tongue better suited

Results: Compressor Map



- Hurst exponent (based on outlet pressure):
  - H > 0.5 at peak efficiency
  - 0.15 < H < 0.5 at low mass flows
  - H < 0.15 in deep surge
- Monofractal – multifractal distinction has potential as early warning

Summary and Outlook

- Hurst exponent as surge indicator:
  - \+ Well-defined limit H=0 for pure oscillations
  - \+ Potential as early warning indicator
  - • Many tuning parameters for the algorithm
  - \- Complexity of the concept

- Future plans:
  - Test on engine intake geometry (filter, resonators)
  - Artificial pressure pulse at outlet (simulate intake valves)

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