The Power of Data in the GT Industry:
How to Get Most of it?

Herwart Hönen

h_hoenen@hoenen-cs.de

Better information about the condition of the machine => More instrumentation can create additional data

Are advanced techniques always the appropriate solution?

Better information about the condition of the machine => More instrumentation can create additional data

Are advanced techniques always the appropriate solution?

Mature Measuring Techniques

➢ Robust

➢ Reliable

➢ Cheap

➢ Easy to handle

Advanced Measuring Techniques

➢ Sensitive

➢ Limited long term stability

➢ Expensive

Can existing measuring data or additional mature techniques
be used/applied to provide the required information?

Available information from the machine

➢ Standard measurements

  ▪ Aero-thermodynamic data (steady)

  ▪ Vibration / stress data (steady & unsteady)

  ▪ Power output/input

  ▪ Rotor speed

➢ Mature and reliable measuring techniques
   (wall pressures, pressure & temperature rakes, accelerometers, etc.)

➢ Cheap

➢ Robust
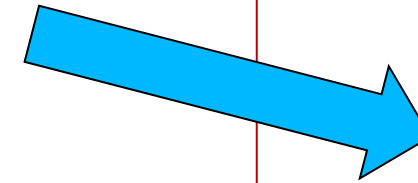
Necessary for control of operating point
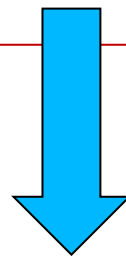
Extraction of additional information

~~**Hönen CS**~~ →

Basis for decision: Required monitoring results

> Possiblity to obtain the information from existing aero-thermo dynamic data

- Correlation of data / results
- Making use of performance maps of compressor & turbine

- Application of 1D calculation tools
- New algorithms
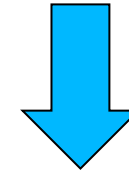 - Application of 2D CFD
- Others (i.e AI)

Examples

Calculation of total pressures in stages based on mass flow + static wall pressures

⬇
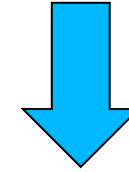
Total pressure in stages
- stage performance

⬇

Flow angles in stages
- stage performance
- localisation of affected stages

~~Hönen~~ CS

Basis for decision: Required monitoring results

➢ Possibilities for additional
(mature) instrumentation in the machine

- ▪ Standard measuring techniques

- ▪ Enhanced standard measuring techniques
(considering harsh environment)

Steady (eg. as replaced borescope plugs)

➢ Additional pneumatic wall pressure taps
➢ Thermo-couples for (material) temperature
measurements
➢ Additional total pressure rakes & probes
➢ Total temperature rakes & probes

Unsteady (eg. as replaced borescope plugs)

➢ Dynamic pressure sensors at side walls
➢ Dynamic total pressure probes

Combustion fluctuations

Wish for advanced instrumentation from customer:

- ➢ High temperature dynamic pressure sensors for combustion chamber

Problems:

- ➢ Availability (time frame)
- ➢ Long term robustness
- ➢ Cost (e.g. fiber optic sensors & electronics)

Alternative solution:

- ➢ Noise measurements outside combustion chamber
- ➢ Extraction of signal portions due to combustion fluctuations by ANNs

Advantages:

- ➢ Immediately applicable
- ➢ Robust
- ➢ Reliable
- ➢ Cheap

Detection/Prediction of Rotating Stall & Surge

Wish for advanced instrumentation from customer :

➢ High temperature dynamic pressure sensors for rear compressor stages

Problems:

➢ Long term robustness

➢ Cost (e.g. fiber optic sensors & electronics)

Alternative solution:

➢ Piezo-electric sensors + cooling adaptors

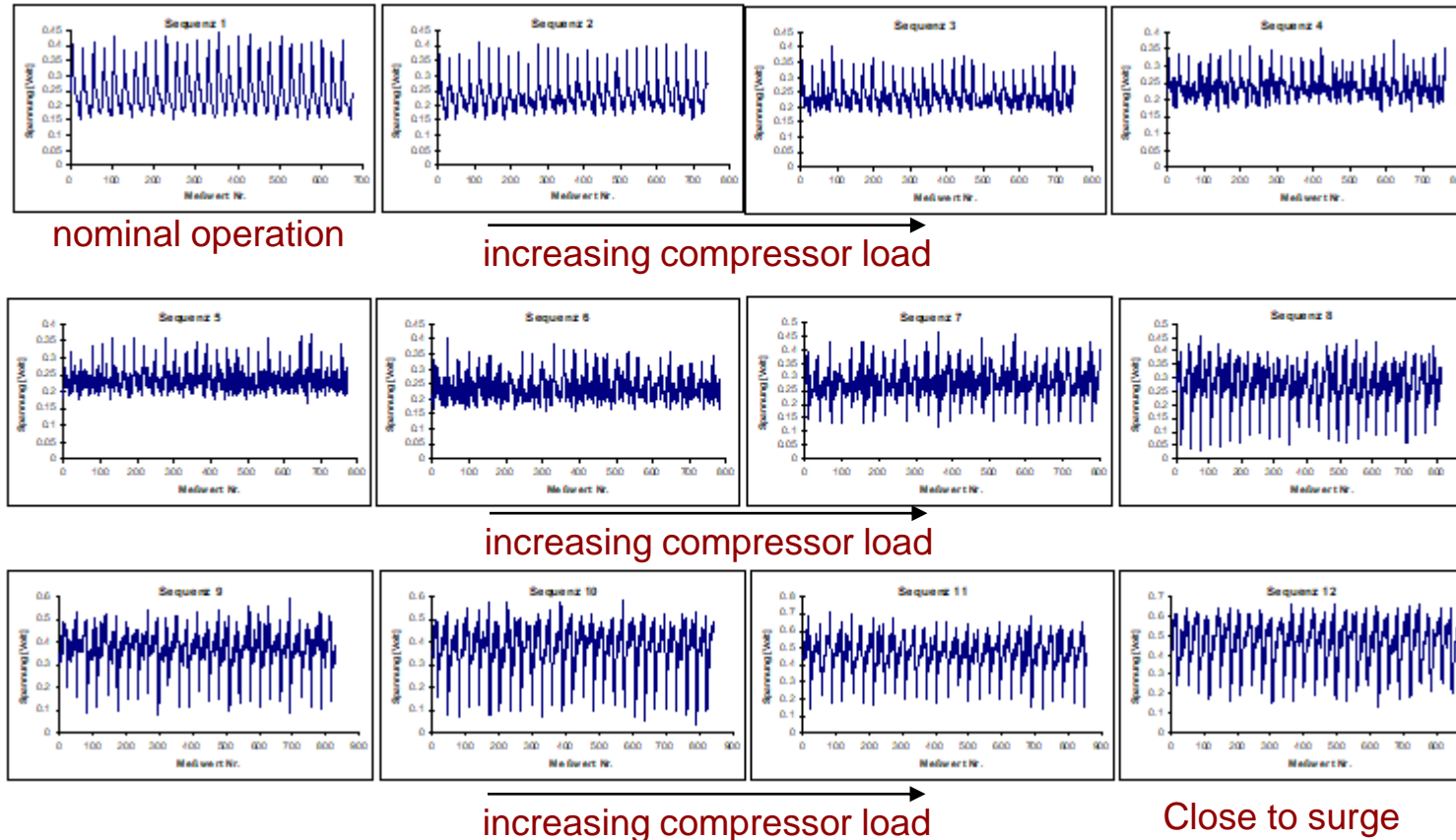➢ Judgement of aerodynamic load by pattern recognition with ANNs

Advantages:

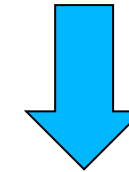➢ Immediately applicable

➢ Robust

➢ Reliable

➢ Cheap

Hönen CS

Dynamic pressure sensors in a GT compressor stage

nominal operation

increasing compressor load

increasing compressor load

increasing compressor load

Close to surge

➢ Development of the pressure signals for different compressor loads

➢ Analysis of the patterns by an ANN

Early warning/alarm possible

ETN Global

Timely Limited Additional (Mature) Instrumentation
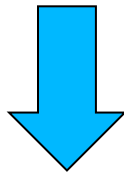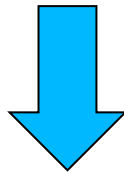
Pneumatic pressure & total temperature probes

Flow field measurements inside stages

- Pressure & temperature distributions
- Flow angle distributions
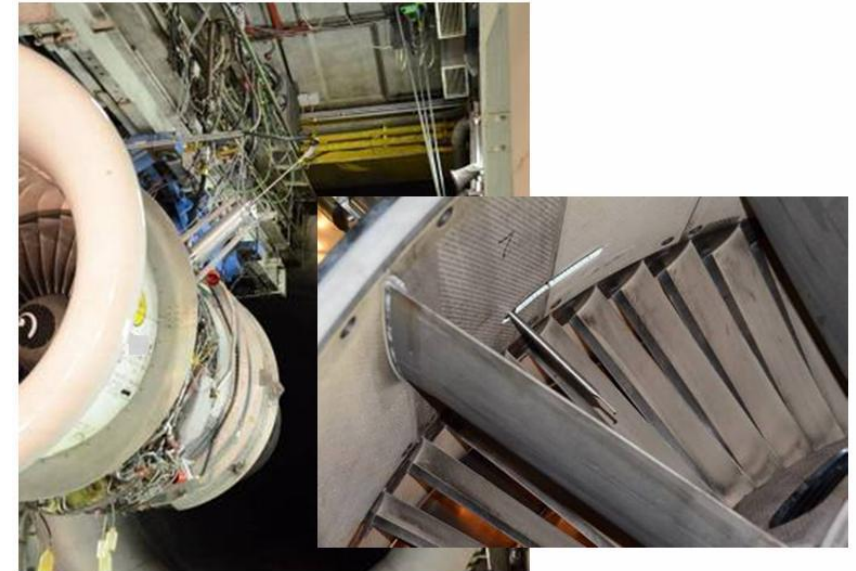- Flow velocity distributions
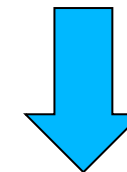
⬇

Data base of flow properties

⬇

Application of ANN to generate correlations beetween flow properties and data from standard instrumentation

Example:
Pneumatic 5-hole probe in a jet engine compressor

Correlation between flow field data and airfoil wear

⬇

Target: Better decision about maintenance/refurbishment

Hönen CS

Advanced information from the machine

➢ Additional measuring locations throughout the machine (information from stages / stage groups)

➢ Application of probes / rakes inside machine (information about losses)

➢ Implementation of dynamic sensors in rakes / probes (unsteady flow behavior as an indicator for problems)

➢ Application of advanced analysis techniques (improving the value of measuring data)

The potential of existing / additional mature measuring techniques should be utilized by application of

➢ New / advanced analysis algorithms

➢ Artificial intelligence

Advanced (sensitive) sensors should preferably be applied in test facilities

➢ Generation of data bases for the application of above algorithms

➢ Generation of knowledge about dependencies between flow properties and measuring data

ETN
Global