Virtualization of the DLR Turbine Test Facility NG-Turb

Next Generation Turbine Test Facility (NG-Turb)

Topics and characteristics:
- Aerodynamic investigations of high-, intermediate- or low-pressure turbines
- Simulation of cooling (realistic density ratio)
- Application of combustor simulators (combustor-turbine interaction)
- Closed circuit (independent variation of Mach- and Reynolds-number)
- 650 temperature measuring points and 600 pressure tappings are possible
- More than a kilometer of piping
- Flow circuit with three main paths (hot and cold path, compressor bypass)
- More than 12 auxiliary units (cooling air, drier, cooler, heater, etc.)

Main performance data:
- Gear compressor (3 stages, pressure ratio ≤ 14, mass flow ≤ 10 kg/s)
- One or two shaft turbine configurations up to 2½ stages
- Turbine inlet pressure ≤ 195 kPa
- Turbine inlet temperature ≤ 540 K
- Turbine shaft power ≤ 1,800 / 1,000 kW (1st / 2nd shaft)
- Turbine speed ≤ 8,000 / 13,000 RPM (1st / 2nd shaft)
- Turbine tip diameter ≤ 900 mm
- Cooling air supply: (≤ 450 kPa, ≤ 2 kg/s)

Why is a virtual representation needed?
- Prediction of operating states and feasible operation conditions for future rig tests
- Optimization of the operational performance:
  - Reduce power and auxiliary media consumption
  - Improve process stability
  - Increase testing time
  - Reduce operating cost
- Assessment of cycle modifications, for instance, how it is possible to:
  - Reduce the compressor outlet temperature?
  - Reach lower turbine pressure ratios?
  - Optimize the use of water cooler and electric heater?

Approach via the Gas Turbine Laboratory (GTlab)

Interactive environment for preliminary design and simulation of aero engines and stationary gas turbines

- DLR in-house developed plugin-based software framework with GUI
- Platform independent
- High modularity for the extension of different functionalities
- Central data model as a basis for the exchange of input and output data
- Initial developed for open cycle simulations Adaptation for closed circuit are now integrated

Virtualization:
- Digital representations of the thermodynamic behavior for the main components (Fig. 3)
  - Compressor
  - Water cooler
  - Electric heater
  - Different valves and piping elements
- Thermodynamic synthesis of the performance components and adaption of the existing models for steady state simulations

Application:
- Sufficient agreement with manufacturer component calculations and measurement data at compressor design points
- Quantification of control variable influences for certain operating points through parameter studies in consideration of given test bench limits
- Compressor simulation shows the potential of lower spool speeds to reach needed lower outlet temperatures and turbine pressure ratios (Fig. 4) Leads to realized implementation
- Comparison with real compressor measurement data shows deviations at off-design conditions
  - Create compressor maps based on continually growing measurement data

Outlook:
- Completing the compressor map generation
- Validate simulations to further measurement data
- Implement transient calculation methods (facility heating up and cooling down)
- Increase the level of details in the simulations

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