Virtualization of the DLR Turbine Test Facility NG-Turb

Next Generation Turbine Test Facility (NG-Turb)

Figure 1: 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 ≤ 195kPa
- Turbine inlet temperature ≤ 540 K
- Turbine shaft power ≤ 1,800 / 1,000 kW (1^{st} / 2^{nd} shaft)
- Turbine speed ≤ 8,000 / 13,000 RPM (1^{st} / 2^{nd} shaft)
- Turbine tip diameter ≤ 900 mm
- Cooling air supply: (≤ 450 kPa, ≤ 2 kg/s)
- ⇨ Feasibility of parameter combinations needs to be pre-checked

Abstraction

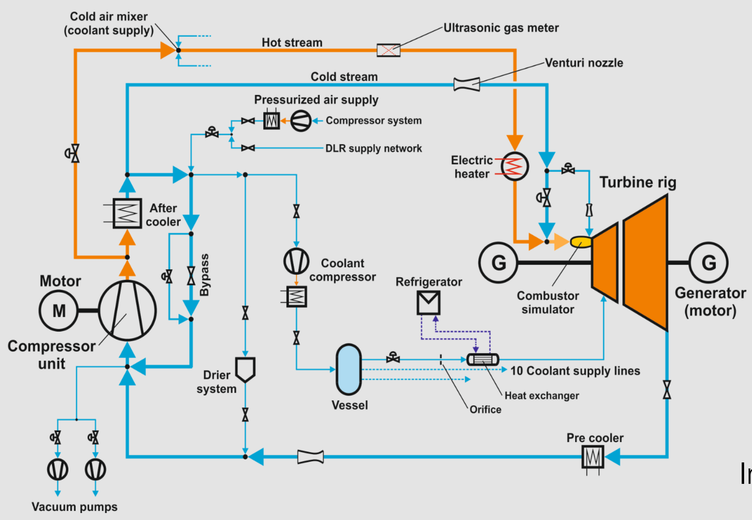

Figure 2: NG-Turb circuit diagram (schematic)

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 is it 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 ⇨ Adaption for closed circuit are now integrated

Virtualization

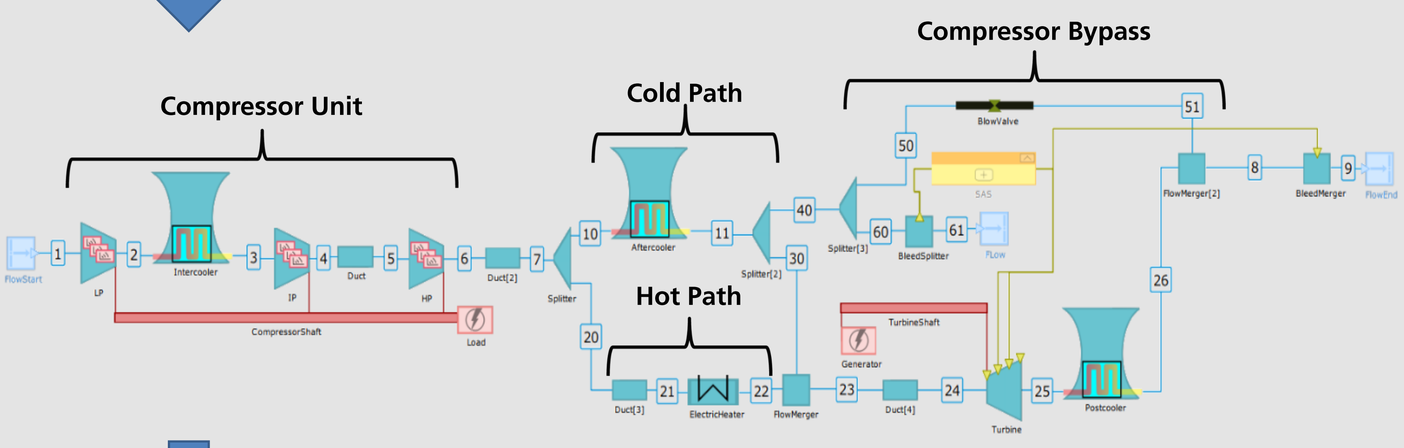

Figure 3: NG-Turb circuit (GTlab)

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

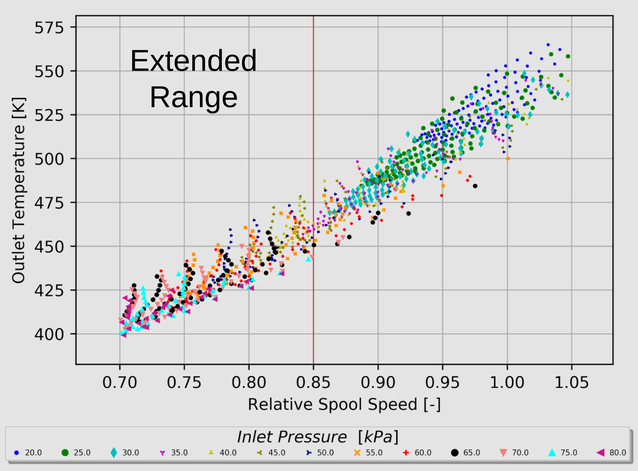

Figure 4: Simulation of the compressor unit with extended spool speed range

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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Contact:

NG-Turb
Institute of Propulsion Technology
Franz-Xaver König
Franz-Xaver.Koenig@dlr.de
+49 551 709-2168
dlr.de/at

Virtualization of the NG-Turb
Institute of Propulsion Technology
Björn Schneider
bjoern.schneider@dlr.de
+49 2203 601-2642
dlr.de/at

Deutsches Zentrum für Luft- und Raumfahrt