Rotor Test Facility for aero-/thermodynamic Experiments - including a Brush Seal Test Rig -

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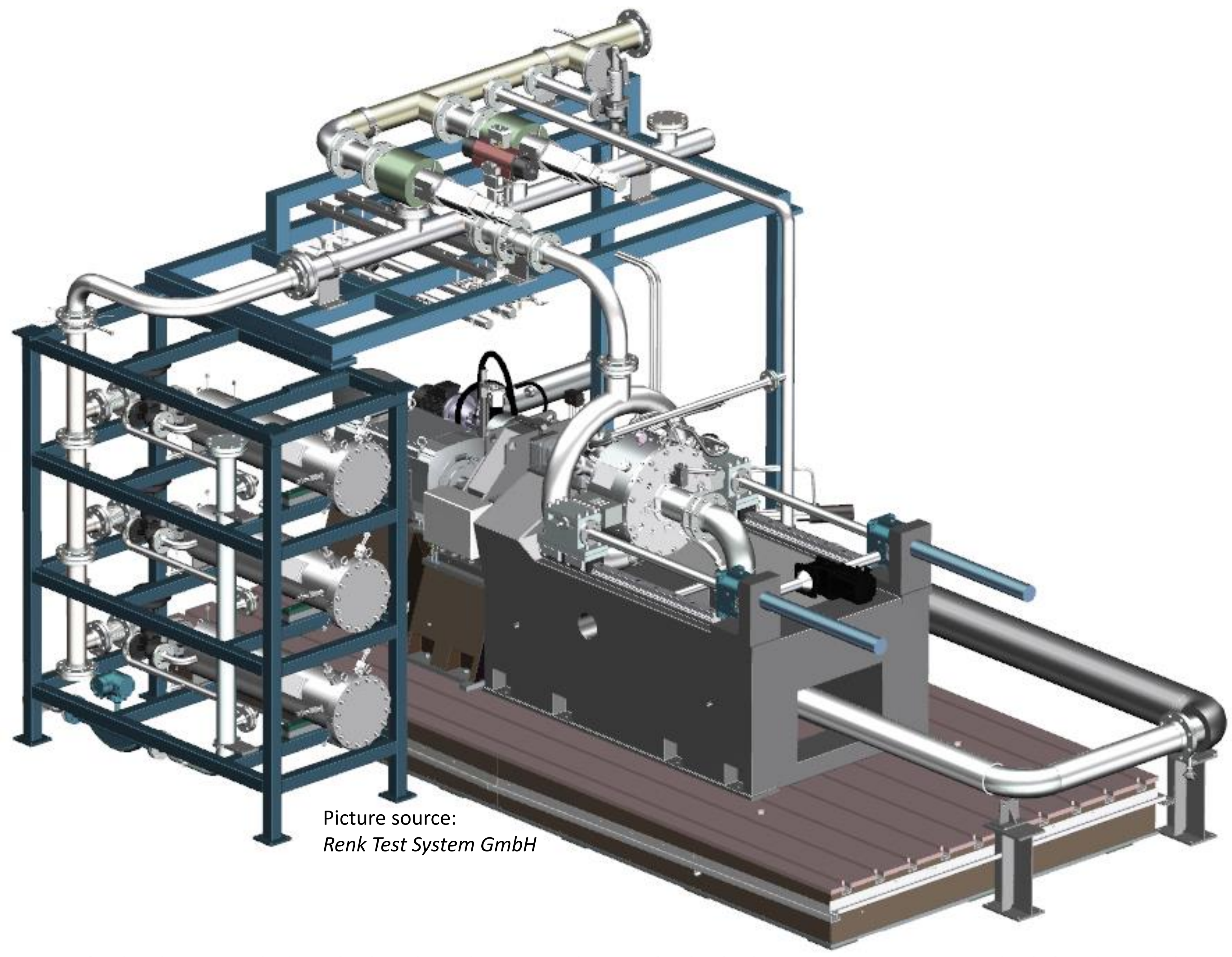


Rotor test facility layout including the brush seal test rig. The test facility's three air heaters are on the left side and the driving system can be seen in the background. The brush seal rig is located in the foreground on the grey frame and connected to the air flow control on the upper side and the mass flow measurements on the right

Motivation

Over the last decade one of the main drivers for increasing efficiencies in gas turbines is a higher turbine inlet temperature, which directly improves the thermodynamic cycle. This comes with increased challenges regarding turbine cooling, though.
The cooling for the rotating parts of the turbine is supplied by cooling air transported inside the rotating system. Inside the rotating system and at the interfaces between rotating and non-rotating parts, many aero- and thermodynamic questions are still waiting for detailed investigations.
One important element in this so called *secondary air system* are air seals to reduce and control leakage flows through gaps. Brush seals are one of the sealing elements used regularly. Due to their tolerance to temporary contact between moving and static part they offer advantages in efficiency and space requirements over labyrinth seals. But their more complex operating behavior is still a subject of current research. To broaden brush seals' operating range regarding surface speeds and temperatures, new materials must be validated. Different material pairings for bristles and rotor show individual wear and friction behavior and must therefore be investigated for every combination. Friction also results in significant heat flow into the involved parts, which has to be considered during engine part design.

The test facility

The Rotor Test Facility enables aero- and thermodynamic component testing in engine-like operating conditions. These are:

- air mass flow: 1 kg/s
- air temperature: 500 °C (400 °C at 1 kg/s)
- pressure loss: 15 bar
- rotating speeds: 27.000 rpm
- drive power: 170kW

To provide the air flow the test stand is connect to a customary screw compressor system.

Downstream three parallel air heaters offer a wide range of possible operating temperatures. A silenced hot gas chimney takes the exhaust air outside.

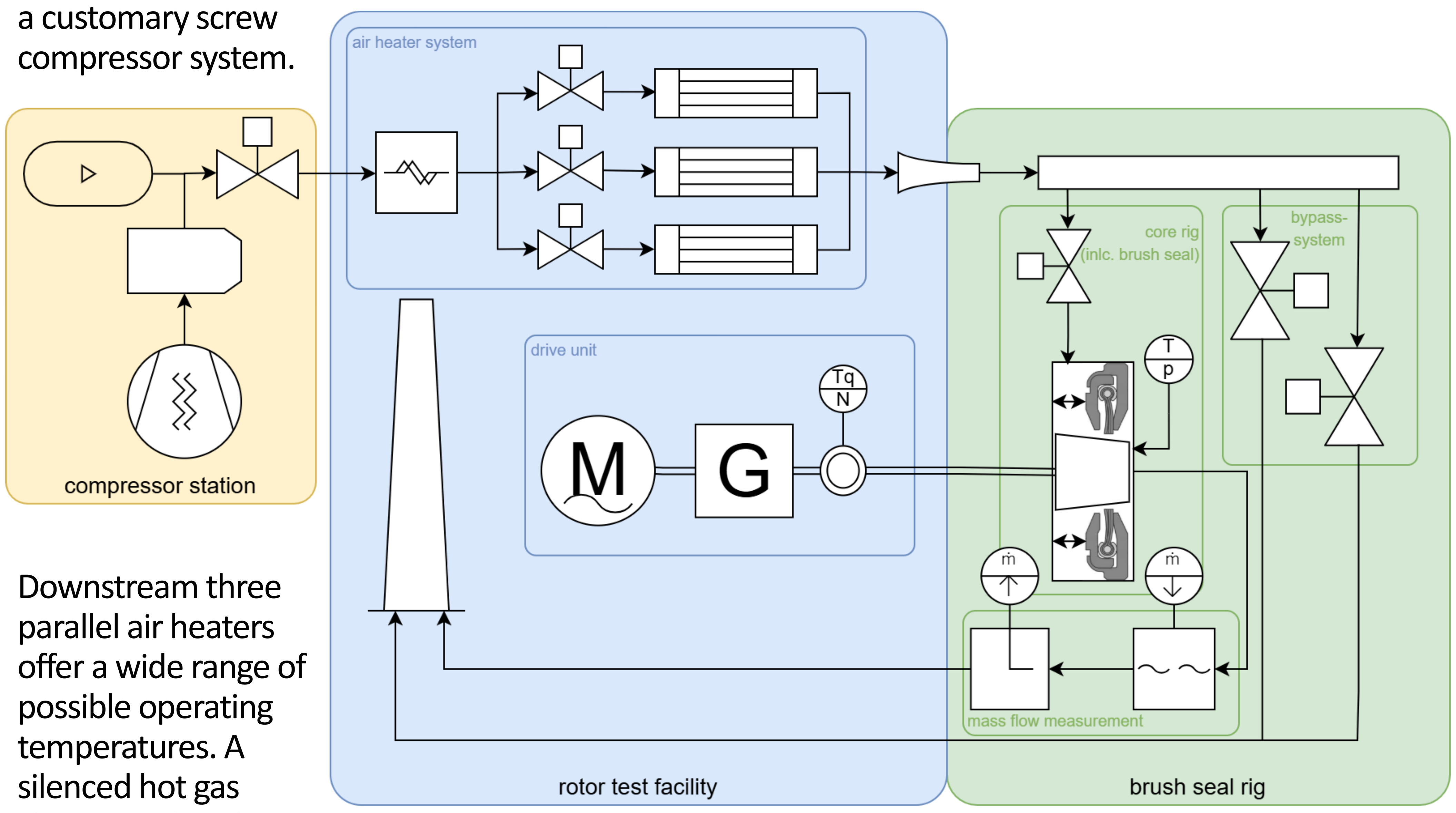
The drive train is realized with a frequency-controlled electric engine. To achieve the high rotating speeds a 1:6 gearbox is installed. Appropriate hydraulics provide gearbox and bearing block lubrication for test bench and test rig.

The brush seal test rig

To investigate the operating behavior, including wear and heat flow phenomena of brush seals, a specific test rig is designed. It operates the seal in gas turbine-like environmental conditions:

- leakage flow: 0,03 … 1 kg/s
- pressure difference: ≈ 4 bar
- rotor surface speed: 410 m/s
- sealing gap: -0.2 … +0.2 mm

To manipulate the upstream pressure of the seal a bypass control valve system is used. The rigs inflow is provided by a critical flow nozzle. This almost constant inflow is then directed either via the bypass valves or the brush seal. When the seal closes, the bypass opens and vice versa.
The sealing gap between bristles and rotor can be adjusted by moving the brush seal in the axial direction on the conical rotor surface. For this movement the casing which includes the seal-mounting is mounted on linear bearings and moved by an electric spindle drive. The absolute position is given by a precise linear encoder. Together with the point of first contact and the conical rotor, this allows exact sealing-gap adjustments. A preset eccentric seal mounting allows eccentric seal/rotor-contact. To characterize the sealing's behavior numerous temperature and pressure sensors measure air and material conditions. Additionally, an optical access allows in-situ investigations of the bristles and the sealing gap. A mass flow measuring tube including an ultrasonic and a dynamic pressure sensor for different ranges enables highly accurate leakage flow measurements through the seal.



Schematic view of the test facilities set-up including the compressor station (yellow) and the rig (green). Air flow is represented by a single line, shaft power by a double line. The circles show important measurement positions

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