Laser-Doppler-Velocimetry measurements in a one and a half stage transonic test turbine with different angular stator-stator positions

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A one and a half stage transonic turbine was tested using a two component Laser-Doppler-Velocimetry system. The measurements were carried out in order to record rotor phase resolved velocity, flow angle and turbulence distributions upstream and downstream of the second stator row at several different angular stator-stator positions ("clocking" positions). Altogether, the measurements downstream of the second stator were performed for ten different clocking positions and upstream of the second stator for two different clocking positions. The paper shows that different clocking positions have a significant influence on the flow field upstream and downstream of the second stator.

1. Introduction and Experimental Setup

For industrial gas turbines the trend is towards higher efficiency at constant and possibly decreasing costs per kW shaft power. Decreasing costs mean that the number of stages is reduced resulting in high-pressure ratios thus leading to transonic conditions for these stages. The demand for efficiency increase leads to a higher importance of unsteady flow effects strongly related to the relative motion between stator and rotor. In multistage turbines this unsteady mixing of stator and rotor wakes and shocks from sequent stages results in a complex situation for numerical flow predictions.

In 1999 the transonic test turbine of Graz University of Technology went in operation, a continuously operating cold-flow open-circuit facility, which allows the testing of turbine stages with a diameter up to 800 mm in full flow similarity. Fig.1 gives the meridional section of the 1½ turbine stage investigated (24 stator vanes were followed by 36 rotor blades and additional 24 stator vanes in the 2nd stator). The tests were performed at 10600 rpm and at a pressure ratio of 4.27 over all stages using a two-component

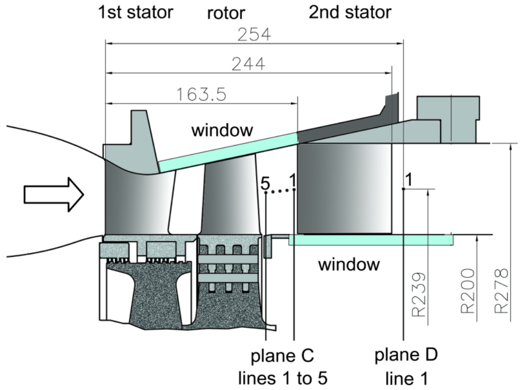

Fig. 1: meriodional section of the transonic turbine (1½ stage), The dots indicate the measurement positions along five lines between the rotor and the 2nd stator and along one line behind the 2nd stator.

LDV-system (DANTEC FiberFlow with two BSA processors). To allow analysis of the measured velocity bursts relative to the angular position of the rotor for each position traversed, a trigger signal provided by the vibration monitoring system of the shaft of the turbine.

2. Results

It turned out that the clocking position in which the wake of the 1st stator blades passes the vanes of the 2nd stator close to the pressure side is favorable in terms of low turbulent kinetic energy and little periodic fluctuations within the flow downstream the 2nd stator. In all other positions a more or less pronounced adverse effects on the suction side boundary layer of the 2nd stator was observed. Additional to this effect a number of other effects were observed usually present in high-pressure turbine stages: a) locking of the vortex shedding from the blades trailing edges to the rotor blade passing period due to the influence of shock systems moving throughout the flow field; b) periodical modulation of the shock systems at the rotor by passing vortices and pressure fields; c) interference of vortices shedding from stator vanes and rotor blades.

Due to the high frequencies involved, tracer particles acted as low pass filter to higher order modulations of certain flow phenomena (e.g. vortex shedding). Additionally, boundary layer material shedding at such high frequency is purged from tracer particles; the uncertainty within these regions was increased due to a lack of samples for the ensemble averaging.

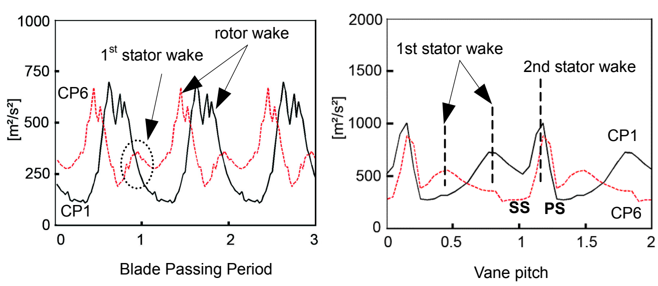

Fig. 2: **Left:** turbulent kinetic energy (TKE) recorded in a position in front of the 2nd stator vane for two different clocking positions (CP1 and CP6). While the rotor blades pass by, the impingement of the rotor wake and the chopped wake of the 1st stator can be observed. The TKE amplitude for CP1 is higher by 13%. **Right:** time averaged TKE behind the 2nd stator (one vane pitch). For CP6 the wake of the 1st stator passed close to the pressure side (PS) of the 2nd stator, the flow is more uniform than with the 1st stator's wake passing close to the suction side (SS) of the 2nd wake.

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