UNSTEADY PERFORMANCE OF A TURBO-COMPRESSOR DURING SURGE

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ABSTRACT

The performance of a turbo-compressor is typically described by the evolution of the pressure rise versus the corrected mass flow rate. These quantities are well defined and easily measured during the steady and stable operation of the turbo-compressor, when its rotational speed and the total pressure losses in the system where it is included are constant over time. However, it becomes very challenging to do so when the aforementioned parameters change with time or the compressor experiences unsteady regime like rotating stall or unstable regimes such as mild or deep surge.

Whereas the time-dependent static pressure rise may be easily acquired by high-frequency pressure sensors (see Figure 1), the determination of the time-dependent corrected mass flow rate is much trickier since it is an integral quantity which theoretically requires the knowledge of the time-dependent velocity and density fields. In order to overcome it, a specific device has been developed together with its data post-processing. This device, described in the first part of the paper, consists of a symmetrical Venturi tube with slowly varying cross-sectional area. It is equipped with high-frequency unsteady pressure transducers at the inlet, throat and outlet stations. Recordings of theses static pressures are used as boundary conditions to numerically solve the compressible unsteady quasi-one dimensional Euler system of equations. The flow model takes into account the contribution of wall friction. This task is performed by implementing a finite-volume method with high-order accuracy schemes in space and time. Under these assumptions, the time-dependent corrected mass flow rate through the turbo-compressor can be determined a posteriori.

As an example of application, the second part of the paper addresses the unsteady performance determination of a small turbo-compressor for fuel-cell application which has been experimentally investigated at different rotational speeds. At low rotational speed, rotating stall characterized by one stall cell rotating at 6.4% of the rotor speed is evidenced [1]. During this rotating stall phase, the corrected mass-flow rate varies in time with small amplitude and remains positive. At high rotational speed, the compressor surges abruptly with no pre-stall activity; the mass-flow rate exhibits large variations and becomes negative over short periods of time. The time-dependent trajectories of the compressor operating point during rotating stall and during surge are determined, leading to a comprehensive representation of the time-dependent performance of the compressor.

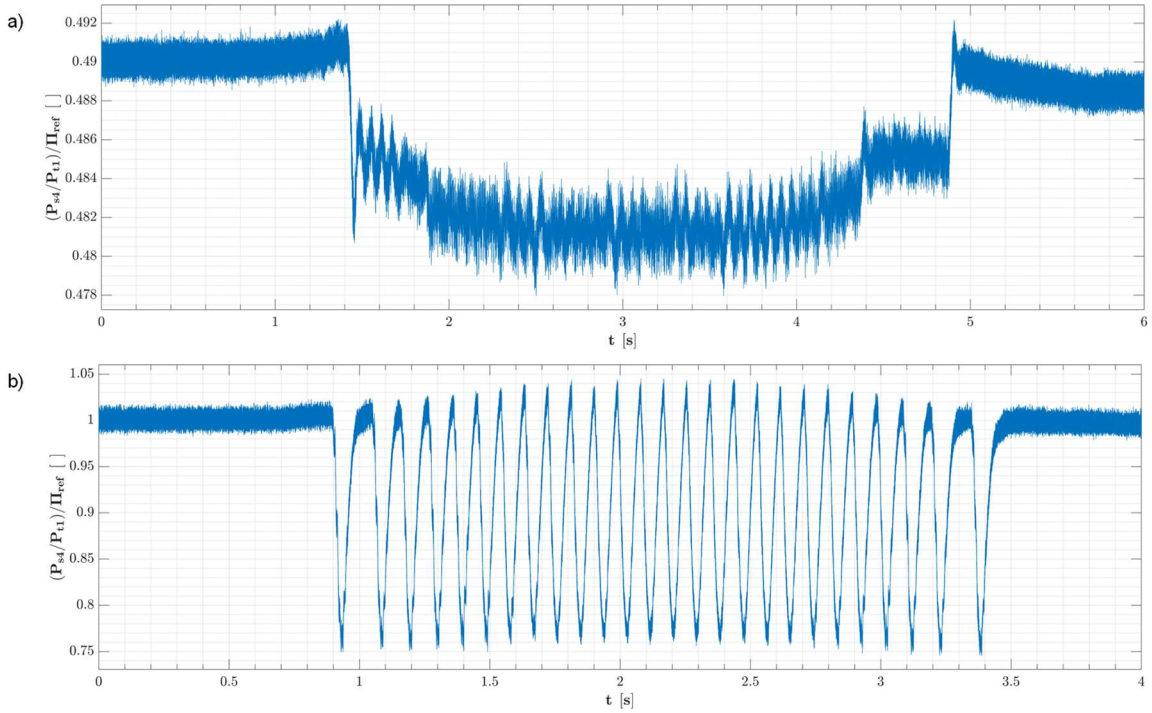

Figure 1. Time evolution of the normalized static-to-total pressure ratio during rotating stall (a) and during surge (b).

REFERENCES

[1] Godard A., I. Trébinjac I., Roumeas M., *Experimental characterization of the surge onset in a turbo-compressor for fuel cell application*, European Turbomachinery Conference 12, Stockholm, Sweden, 2017.