Modeling for control of a centrifugal compression system

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Introduction

The performance and operating range of centrifugal compressors is limited by the occurrence of an aerodynamic instability called *surge*. This instability can lead to severe damage of the machine due to large mechanical and thermal loads. A way to cope with this instability is active control. In this approach, perturbations are fed back into the flow field in order to modify the dynamics of the compression system. Such techniques can extend the stable operating range towards lower mass flows, which makes the compressor more versatile. See also Figure 1. Furthermore it enables the safe operation of the compressor near the surge point.

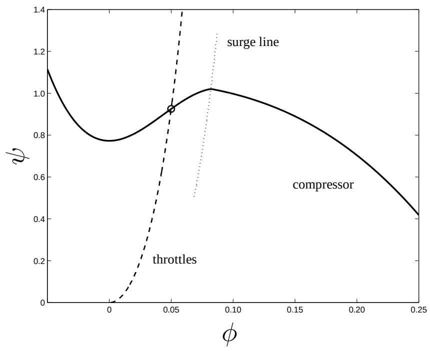

Figure 1: Compressor curve with unstable operating point.

Compression system model

The suggested approach is applied to an experimental compression system with a rated power of 250 kW. To describe the dynamic behaviour of the examined compression system, the model suggested in [1] is used. The lumped parameter model is schematically shown in Figure 2. By introducing a dimensionless mass flow ϕ, pressure rise ψ, and time scale $\tilde{t}$, the following set of equations is obtained

$$\frac{d\phi_c}{d\tilde{t}} = B(\psi_c - \psi) \tag{1}$$

$$\frac{d\psi}{d\tilde{t}} = \frac{F}{B}(\phi_c - \phi_l - \phi_s) \tag{2}$$

where ψ_c represents the nonlinear steady-state compressor pressure rise shown in Figure 1. The parameters ϕ_l and ϕ_s represent relations for the throttle mass flows.

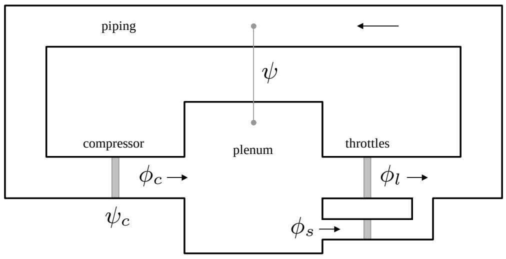

Figure 2: Lumped parameter compression system model.

Model validation

In order to validate the obtained model, simulation results are compared with experimental surge measurements. Figure 3 shows that both the amplitude and frequency of the surge oscillations are captured well by the model. Furthermore, a sensitivity analysis is carried out. This analysis provides measures for the relative importance of the various model parameters. The results also form the starting point for the analysis of the linearized model and the design of a stabilizing feedback controller.

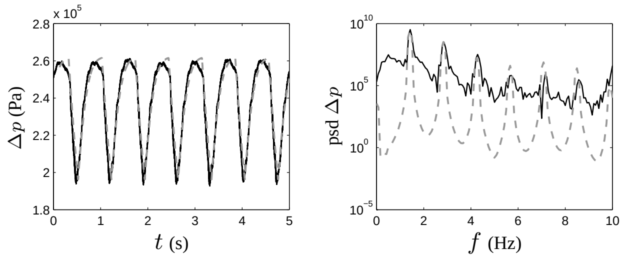

Figure 3: Comparing simulations (- -) with experimental data (–).

Acknowledgement

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References

[1] Greitzer, E.M. (1976), 'Surge and rotating stall in axial flow compressors. Part I: Theoretical compression system model', ASME J. Eng. for Power, **98**(2), 190–198.