TOR – Towards the Energetically Optimal Ventilation System

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Introduction

The understanding that optimized components do not automatically lead to energy-efficient systems shifts the attention from the single component to the entire technical system. Following this insight, a new field of study named "Technical Operations Research" (TOR) [1] was developed at TU Darmstadt. It combines technical and mathematical know-how to accomplish the energy optimal design of technical systems. Ventilation systems play an important role in the context of energy consumption and the potential for improvements still is high [2]. Using the methods of TOR, we are able to find the energetically optimal layout of a ventilation system.

Design process combining discrete optimisation and dimensional analysis

We illustrate our optimisation approach by designing an energetically optimal ventilation system for an office building which contains bureaus and conference rooms. Considering the time-dependent occupation density of these rooms (cf. **Figure 1**), we derive a temporal distribution of different loading demands for our future ventilation system. Hence, not only a single operating point, but multiple demands at the same time are considered in the design process. Towards the optimal design of the ventilation system, discrete decisions have to be answered, like: *Is the use of multiple smaller fans more efficient than one big fan?* Each decision affects the energy consumption of the system. We specify a kit of potential axial fans out of which we build the ventilation system. Using dimensional analysis we represent the fans by dimensionless curves: pressure coefficient and efficiency versus flow coefficient. By applying affinity laws for turbomachines

$$\psi = \frac{\Delta p}{\frac{\pi^2}{2}\rho n^2 d^2}, \qquad \varphi = \frac{\dot{V}}{\frac{\pi^2}{4} n d^3}, \qquad \lambda = \frac{P_S}{\frac{\pi^4}{8}\rho n^3 d^5}, \tag{3}$$

the variation of the diameter d and rotating speed n allows us to create head curves for different fan sizes with variable rotating speed, as shown in **Figure 2**. In this way we are able to represent one product line of fans based on geometric similarity. Furthermore the influence of the Reynolds number on the efficiency is taken into account based on a scaling law published by PELZ et. al. [3].

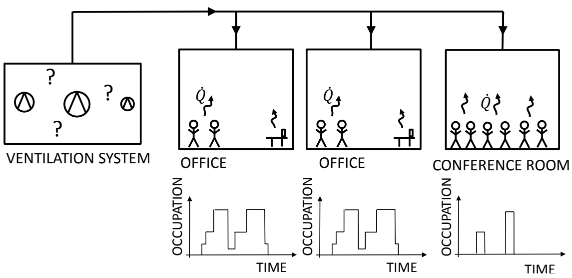

Figure 1: Office rooms with varying occupation density.

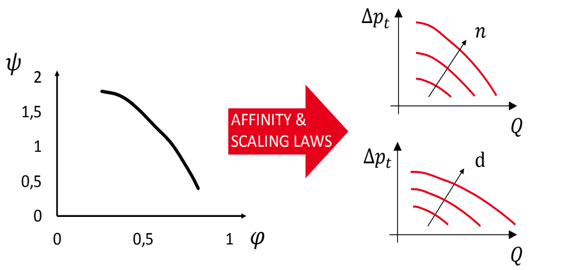

Figure 2: From dimensionless head curves to a product line.

Modelling the potential layouts of the system by a Mixed Integer Program our discrete optimization algorithm finds the global optimal one, i.e., it finds the most energy-efficient ventilation system.

Conclusions

In the design process of a ventilation system not only one operation point but a temporal distribution of different loading demands are considered. Despite of numerous different ventilation system designs and control options, TOR allows us to simultaneously find the energetically optimal combination of fans and the most energy-saving control settings that yield the best energy-efficiency. What distinguishes our approach from conventional heuristics like genetic algorithms is the inherent objective quality criterion. With Mixed Integer Programming we are able to assess solution proposals and to find the global optimal one.

References:

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