Aerodynamic Optimization of Centrifugal Fans Using Active Learning

Due to their significant contribution to the total electricity consumption of the European Union (nearly 10%), future minimum efficiency requirements for fans are set by EU regulations. As a consequence, many currently available fans on the EU market may no longer be sold and the need for efficient design and optimization methods arises. In the context of the current project we focus on centrifugal fans.

This project aims to build a general metamodel for the efficiency prediction of centrifugal fans depending on their geometry. A metamodel is a computationally inexpensive „model of a model" that tries to approximate a computationally expensive simulation with high accuracy. Here computational fluid dynamics (CFD) simulations should be substituted by a neural network (NN). Through the usage of computationally inexpensive NNs, extensive optimization runs become feasible for a variety of operating points.

For the generation of accurate NNs, examples are needed where geometry parameters of a fan are linked with the resulting aerodynamic properties. Through a training algorithm, the NN is able to learn the relationship between the inputs (fan geometry) and the outputs (pressure, efficiency) with the help of these examples, such that predictions can be made for any new fan geometry. The used examples for the training come from CFD simulations that have been validated on a test bench for several fan geometries, see Fig. 1.

Methodically, the major outcome of this research project was to demonstrate the benefits which can be achieved by:

- Parameterized characteristic curve description,
- Active learning.

Optimization (Fig. 2) can be carried out in a much more reliable and robust manner if the modelled characteristic efficiency curves meet a pre-defined structure instead of allowing arbitrary curve shapes generated by a neural network.

A new philosophy of active learning triggers new CFD simulations at geometric parameter combinations that simultaneously fulfill the following three properties:

- space-filling,
- improvement of poor model quality regions,
- potential optimality.

This covers the most promising fan geometry candidates.

Figure 3 shows the extension of achievable regions in the Cordier diagram through the active learning strategy. For almost each viable specific fan speed σ, higher specific fan diameters δ are possible. Additionally, lower and higher specific fan speeds could be achieved. The absolute efficiency was improved by up to $\Delta\eta_{ts}$ = 0.3 (≈ 100 %) through the active learning strategy, see Fig. 4. The improvements are mostly achieved above the Cordier curve where the specific fan diameter is relatively high.

I Project Management and Execution

Management:
Univ.-Prof. Dr.-Ing. Oliver Nelles
Univ.-Prof. Dr.-Ing. M.Sc. Thomas Carolus

Contact:
Universität Siegen
Dept. Maschinenbau
Institut für Mechanik und Regelungstechnik - Mechatronik

Paul-Bonatz-Straße 9-11
D-57076 Siegen
E-Mail: oliver.nelles@uni-siegen.de
Telefon: +49 (0) 271/740-4045
Fax: +49 (0) 271/740-2365

Fig. 1:
Test bench for the validation of the computational fluid dynamics (CFD) simulations.

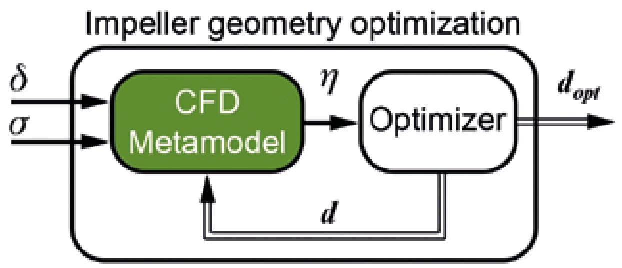

Fig. 2:
Fast optimization procedure utilizing the metamodel

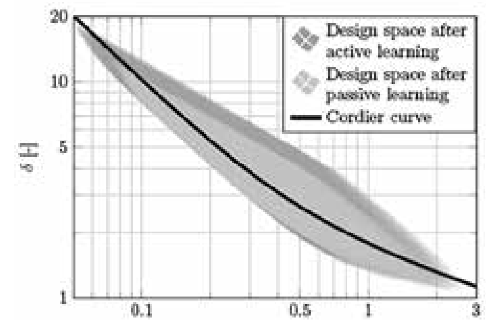

Fig. 3:
Extension of achievable design point area in the Cordier diagram through active learning

Fig. 4:
Absolute efficiencies.
Left: After active learning.
Right: Improvements through active learning.