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Rotor load optimization with a multi fidelity surrogate model

K Loenbaek[a,b]

[a]Technical University of Denmark, Frederiksborgvej 399, 4000 Roskilde, Denmark
[b]Suzlon Blade Science Center, Havneparken 1, 7100 Vejle, Denmark

E-mail: kenneth.loenbaek@suzlon.com

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Wind turbine rotor optimization has been the topic of significant amount research since the start of the wind turbine industry. For many years the target has been to make the most power efficient rotor ($\max C_P$), but that is changing to rotor optimization where load constraints are taken into account.
Previously we have made a relatively simple analytical model (to be published) which relates the rotor loading (C_{LT}) and the rotor power (C_{LP}) at every radial position, with the assumption of radial independence (much like the BEM-model). The model can be used to study the trade-off between loading and power and the optimal load distribution can be found for a given load constraints (e.g. thrust, flap moment, etc.). In figure 1 an example of such a relationship is given for root-Flap-bending-Moment (C_{FM}) and the Power (C_P), where the Local-Thrust (C_{LT}) at some selected points are shown to give an idea for how the load distribution change along the Pareto optimal curve.

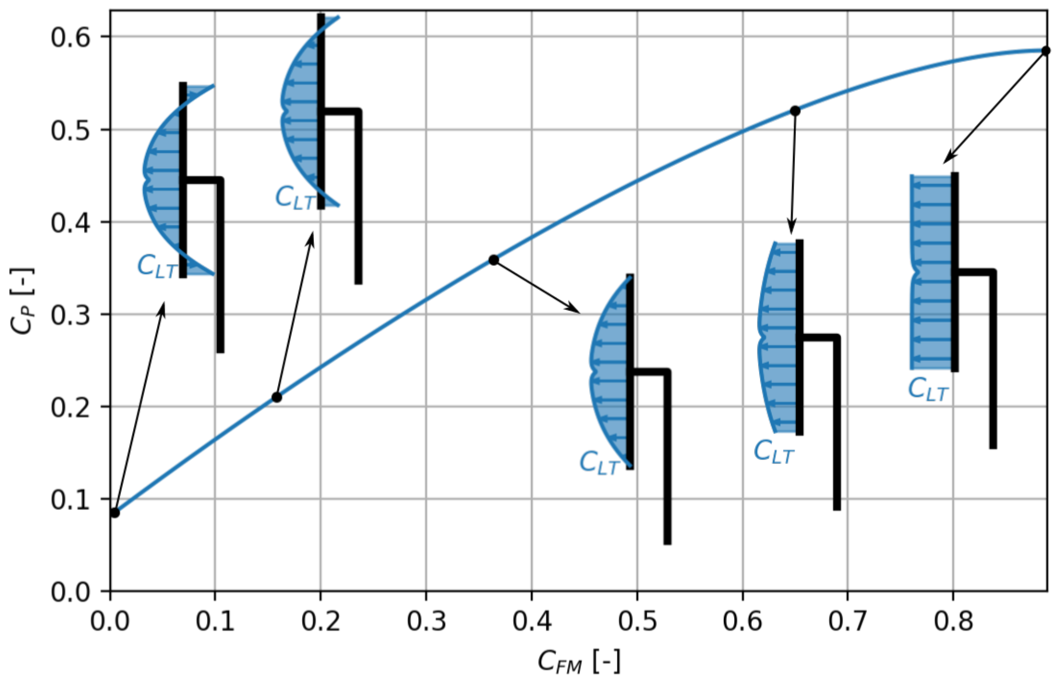

Figure 1: Pareto optimal relationship between root-Flap-bending-Moment-Coefficient (C_{FM}) and Power-Coefficient (C_P). The relationship is computed with an analytical model. The small figures shows the Local-Thrust-Coefficient (C_{LT}) for selected points giving an idea for how the load distribution change along the Pareto optimal curve.

The low fidelity model is good for initial rotor design but for more detailed aerodynamic design the method falls short. In order to capture more of the physics a surrogate correction model will be build to correct the analytical model. The correction model is computationally fast to evaluate and it makes it possible to use almost the same optimization method as for the analytical model.
The correction model will be trained with two different CFD model, which differs in computational speed and fidelity - both of them being 3D CFD model. The first CFD model is an Actuator Disk (AD) model which only requires to set the forces at the rotor disk, which is opposed to specifying a blade geometry. The second CFD model is a rotor simulation where the blade geometry is resolved. The AD model has a shorter computational time but it does not capture as much of the physics. The work will focus on how to incorporate the multi fidelity information in a single design framework. A flow-chart in figure 2 shows an overview of how this framework is going to be connected.
Using the multi fidelity correction model the optimization strategy used for the analytical model can still be used which made the rotor optimization problem simpler and it reduce the amount of optimization parameters. The amount of optimization parameters is a common problem in optimization especially when the amount of simulations that can realistically be made is on the order of 50-100 and the number of parameters is more than 10 (the problem is known as The curse of dimensional). The "trick" used to reduce the amount of parameters is to keep the the radial independence assumption (with some modifications) in which case the optimization problem only leaves one free parameter at each radial station that can be optimized independently of the others.

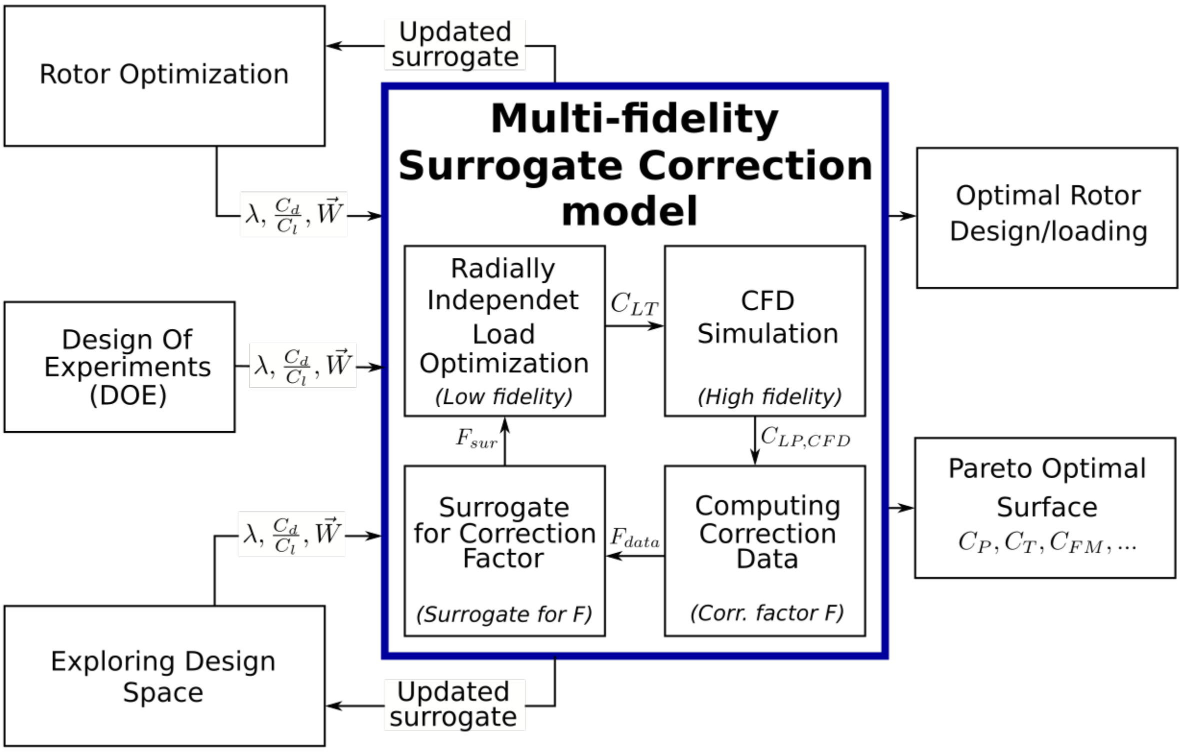

Figure 2: Flow-chart diagram showing how the Multi-fidelity Surrogate Correction model is build. The boxes on the left (Rotor Optimization, DOE, Exploring Design Space) shows the input for constructing the surrogate model. The blue box in the middle contains the diagram for correction model. The boxes on the right is the output from the model.

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