Global sensitivity analysis of model parameters in aeroelastic wind-turbine codes

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1 Introduction

Aeroelastic models such as the Blade Element Momentum (BEM) method [2] continue to play a critical role in the design, development and optimization of modern wind turbines. The accuracy of BEM predictions is affected to by uncertainties and inaccuracies, for example in the external conditions (wind parameters), in the turbine specification (geometric parameters), and in the BEM equations itself (model parameters). For the purpose of design, uncertainty quantification and optimization, is it crucial to limit the number of parameters, typically by performing sensitivity studies. Most studies focused on the effect of uncertainties in the external conditions and in the geometry, see e.g. [3, 5, 6, 8].

2 Objectives

The long-term objective of this study is to develop calibrated BEM models that give users an indication of the uncertainty associated with the predictions (loads, power, etc.) originating not only from external conditions and geometry, but also from the model formulation itself. For this purpose, we will calibrate the model parameters present in BEM models. Examples of such model parameters are the time constant in dynamic stall models, the wake correction factor, the tip loss model parameter, and the lift- and drag-polars [9]. In order to limit the number of model parameters involved in the calibration process, *the objective of the current study is to perform a global sensitivity study of the outputs of the BEM model towards both geometric and model uncertainties.*

3 Methodology

To compute parameter sensitivities we use a global sensitivity analysis based on the Sobol expansion approach, which decomposes the total variance of the quantity of interest (model output) into contributions from individual parameters and their combinations, similar to [3, 6, 7]. We employ the uncertainty quantification toolbox `UQLab` [4], which computes the Sobol indices from a sparse polynomial chaos expansion. `UQLab`'s modular structure allows for easy integration with available BEM codes.

The geometric uncertainties currently considered are chord and twist distribution, whereas the model uncertainty enters via uncertainty in lift- and drag-polars. In order to express the chord, twist, lift and drag distributions along the turbine blade, an efficient parameterization is needed that gives flexible control over the prescribed uncertainty while limit the number of required parameters. We have chosen to use NURBS curves for this purpose, similar to [3].

4 Results

The aeroelastic code that we use is the `ECN Aero-Module` [1] and the turbine is the 2MW NM80 turbine from the DANAERO project [10] with a blade radius of 38.8m. The data for lift (Cl) and drag (Cd) polars are available at four locations along the blade radius at 11.87m, 17.82m, 28.97m and 35.53m. The reference value of polars are obtained from wind-tunnel experiment with 3D corrections. The random sample of chord, twist, lift- and drag-polars are obtained by perturbing the control points with a uniformly distributed random variable. For chord and twist, we independently perturb control points at different locations as shown in Fig. 1 (a)-(b). For each Cl and Cd, all control points are perturbed using a same random variable.

In Fig. 2, we show the total order Sobol indices as a measure of sensitivity for different geometric and model parameters.

5 Conclusions

Global sensitivity analysis is a powerful tool to identify important input parameters associated with aeroelastic models. Sobol indices computed using sparse polynomial expansion is very efficient and can be used to analyze large number of input parameters.

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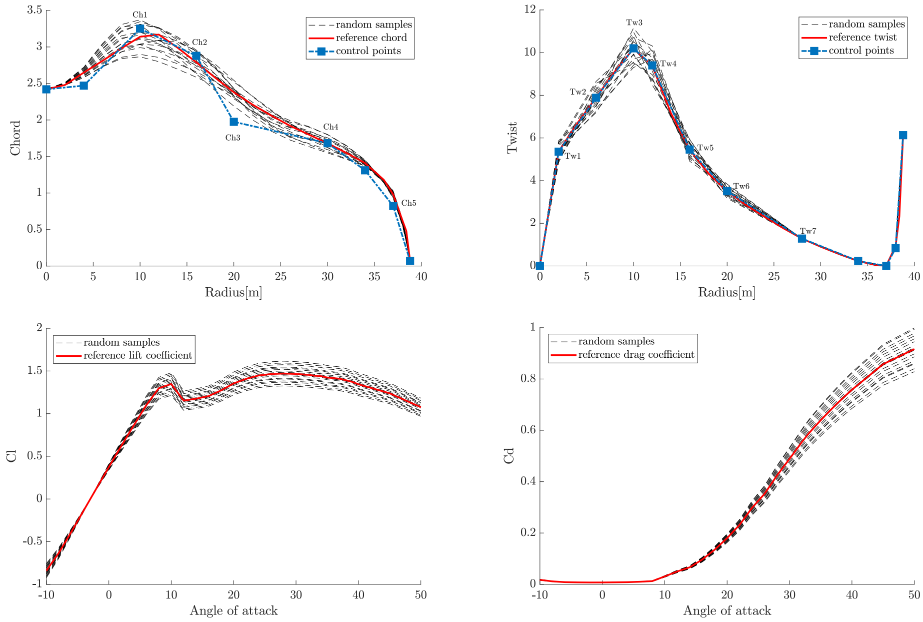

Figure 1: Random realization of twist, chord, lift- and drag-coefficients.

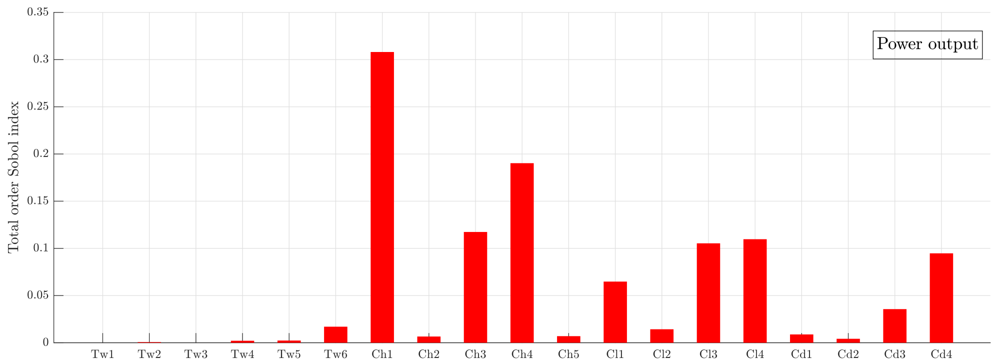

Figure 2: Total order Sobol indices for the sensitivity analysis of geometrical and model parameters.

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