

ADAPTIVE DESIGN OF EXPERIMENTS FOR EFFICIENT AND ACCURATE ESTIMATION OF AERODYNAMIC LOADS

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Abstract

Our ability to obtain accurate prediction of aerodynamic loads for a number of flight conditions prescribed by certification authorities is of primary importance during the early stages of an aircraft process design. The need to explore a high dimensional parameters space using a large number of model evaluations is traditionally addressed by relying heavily on semi-empirical relations and linear assumptions. Despite the availability of high performance facilities where computational fluid dynamics routines could run at an affordable computational cost and provide a higher fidelity of the model outputs, the usage of linear methods is still a common practice for a number of reasons. First, linear methods are corrected to account for un-modelled flow physics. Corrections have been calibrated using a number of previous aircraft configurations, and high confidence exists. Secondly, linear methods are fast enough for parametric searches, and their analysis setup is straightforward practically building on a simplified description of the lifting surfaces.

In addition, an accurate investigation of the design parameter space generally requires a large number of simulations, typically in the order of $O(10^n)$, n being the number of parameters to be investigated. In traditional design of experiment (DOE), the samples to be evaluated are chosen all at the same time, based only on information that is available before running the numerical explorative campaign. The impossibility to know in advance the optimal number of samples that will be required to achieve a given accuracy of the surrogate models built on top of the DOE often leads to over/under sampling problems, resulting in too high computational costs or very poor prediction capabilities, respectively. In this work, we propose to overcome these problems by employing an Adaptive DOE algorithm. The latter is a self-learning technique that makes use of an iterative procedure to (a) identify the regions of the design space that are characterized by stronger non-linearities and (b) select the new samples in order to maximize the information content associated with the simulations to be performed during the next iteration.

The objective of this study is to couple CFD simulations and ADOE in order to (a) iteratively improve the way the CFD analyses are distributed within the design space, (b) obtain a better approximation of the objective function and (c) maximize the information content that can be extracted by a certain number of runs. We test our approach and compare it against more traditional DOE methods by way of a test case based on the transonic cruiser (TCR) model that was developed during the SimSAC (Simulating Aircraft Stability and Control Characteristics for Use in Conceptual Design) project. We show that coupling ADOE and CFD simulations allows obtaining a more accurate prediction of aerodynamic loads at a lower computational cost than the one required by traditional DOE techniques.