Development of Hybrid Optimization Methods with Applications to Turbomachinery Components

Optimization methods are increasingly integrated into the design process of turbomachinery components, as they have proven to reduce the design cost and time while improving product quality. Due to this, they are increasingly used in more elaborate and complex design tasks, which require more efficient and versatile optimization algorithms.

In the optimization field, two main families of methods can be distinguished depending on the order of the derivative of the objective function used. Gradient-free methods use only the value of the objective function while gradient-based methods require additionally the computation of gradient to guide the optimizer towards the optimum. Each of these two families has their own advantages and disadvantages.

In this context, this thesis is dedicated to develop hybrid optimization algorithms which combines gradient-free and gradient based approaches in order to benefit from their respective strengths. In the proposed hybrid methodologies, the gradient-free method and the gradient-based algorithm allow respectively to perform a global exploration of the design space and to accelerate the convergence towards the global optimum.

First, the performance of the proposed hybrid methodologies is assessed on benchmark analytical problems specifically designed to assess the performance of optimization algorithms. The optimization results demonstrate that the proposed hybrid approaches allow to perform a global exploration of the design space at a reduced computational cost compared to classical gradient-free algorithms. The effectiveness of the implemented hybrid methods has been demonstrated on a 2D turbomachinery application, the LS89 turbine cascade. Finally, one of the proposed hybrid optimization algorithms is assessed on a computational demanding 3D turbomachinery test case representative of an industrial problem, the SRV2-O radial compressor. On both test cases a significant improvement in performance could be demonstrated at a reduced computational cost.

In this thesis, another important subject concerning the multimodality of the optimization problems in turbomachinery has been addressed. An investigation regarding the multimodality of the 2D turbomachinery application has been performed and the results obtained in the present work suggest that the LS89 test case is unimodal. In addition, this research also revealed that the multimodality sometimes found in the literature may be caused artificially by inaccurate gradients used during gradient-based optimizations. With inaccurate gradients, the LS89 optimization converged to different sub-optimal designs, which could be misleadingly interpreted as multimodality.