Multi-fidelity Optimization of Compression Systems

by

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The complexity of gas turbine engines has led to the adoption of a highly fragmented, sequential, iterative and hierarchical design process. Traditionally, the design process is subdivided into a number of phases: the conceptual design fixes the values for some global parameters and dimensions to allow the subdivision of the overall task into comparatively simpler problems (the design of individual modules) which are generally dealt with separately by different teams of specialists. Further subdivision is present within the design of each module: in compressor design, mean-line, through-flow and detailed design are generally approached separately, using a range of tools making a disparate set of assumptions and simplifications and thus potentially large areas of disagreement. Refinements to a given design are usually made only within each design phase: the aim of each stage of the design process is the identification of a good starting point for the following stage. This traditional design approach relies heavily on designer experience to make important design choices, with the effect that new designs tend to be evolutions of previous successful solutions.[1] Furthermore, the use of high-fidelity tools is often necessarily limited to the latter stages of the design process, when the design space is often restricted thereby limiting their contribution to the overall process (they can only refine an already established solution). Decisions that more fundamentally determine final system performance are made in the early phases of the design process, using less computationally expensive but lower-fidelity design tools.

In recent years, the use of automatic optimization approaches has increased significantly also in the area of gas turbine design. The main advantages of automatic optimization approaches are the ability to produce a more thorough search of the available design space, making an optimal use of the possibilities introduced by modern technology (such as distributed computing), and the possibility of freeing the designer from the burden of evaluating a large number of design solutions, allowing more time for creative thinking.[2] To the authors' knowledge, one important limitation of the studies presented so far comes from the fact that they approach a specific phase of the design process (engine conceptual design or either preliminary or detailed component design), with the result of improving that specific design phase (and possibly its result) but with a more limited impact on the overall design process.

This study aims to integrate different phases of the design process for a core compression system, by blending tools with different levels of fidelity, ranging from mean-line analysis to three-dimensional Computational Fluid Dynamics (CFD), with the support of an optimization framework. The proposed system aims to produce a (or a range of) high-fidelity design solution(s) for a specific design target, while investigating the impact of modifying the global design variable that usually remain fixed during detailed design.

References

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