# Multi-Objective Preliminary Optimisation of Aero-Engine Compressors

by

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The design of a new compressor for aircraft application is a complex task: design objectives are almost always conflicting (maximum efficiency and surge margin, minimum weight and size), the design space is large, nonlinear and highly constrained and sometimes the effect of some geometrical changes can be difficult to predict.

Computational fluid dynamics (CFD) is now widely used in a number of real-world applications and especially in the design of turbomachinery, having become an essential tool for understanding and modeling three-dimensional flow behaviour. However, the large design space and the time required for the numerical simulation of the whole turbomachine make the use of CFD in the early phases of the design process infeasible. For these reasons, preliminary design relies on a number of physical and empirical relations, still quite similar to the ones used in the early history of turbomachinery design. These rules and correlations allow a more rapid exploration of the design space, with the aim of reducing its size by establishing values for some of the more global variables, while CFD can be used later to validate the design and for further optimisation of more local variables.

The large number of design variables, together with the multi-objective nature of the design and the multimodality of the objective functions, lead to further complications in the optimisation. It is almost impossible, even for an experienced designer, to obtain an optimal design by simple trial and error: more sophisticated tools for exploring the design space are needed to obtain a complete overview.

In this study, 87 independent parameters were used to define the geometry of a 7-stage compressor, the performance of which was evaluated using proprietary codes for mean-line, multi-stage analysis. A multi-objective optimisation of compressor efficiency and surge margin was then conducted by coupling an optimiser to the performance evaluation software. The effects on the performance metrics of changing 44 design variables were analysed and their optimal values found by means of deterministic (gradient-based) [1] and meta-heuristic optimisation methods (Tabu Search) [2].

The results show clearly how the use of meta-heuristic optimisation tools can improve the preliminary design of turbomachinery, allowing a more thorough but still rapid exploration of the design space to identify the most promising regions that will then be verified and further analysed with higher fidelity tools. The results also reveal the impact of introducing various constraints into the design process, highlighting the effects of design decomposition.

## References


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