# Multidisciplinary Design Optimization of Aero-Engine Fan Blades

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**In this paper we present the application of a multidisciplinary and multiobjective optimization system to the design of a transonic fan blade for high bypass ratio turbofan engines. The optimization includes both aerodynamic and structural performance criteria and is based on a two-level strategy consisting of a Differential Evolution algorithm coupled to a Kriging metamodel in order to speed up the optimization process. High-fidelity performance evaluations are carried out by means of 3D Computational Fluid Dynamics and Computational Structural Mechanics analysis tools. The optimization process involves the evaluation of multiple key operating points of the aircraft mission, including top-of-climb, cruise and take-off performances.**

## I. Introduction

In this paper the application of a multidisciplinary and multiobjective optimization system to the design of a high bypass ratio aero-engine fan blade is presented. The optimization method enables the concurrent evaluation of aerodynamic and structural performance criteria, therefore facilitating the identification of the interaction of disciplines and allowing the design to progress towards global optimal solutions in a reduced design time.

## II. Optimization system

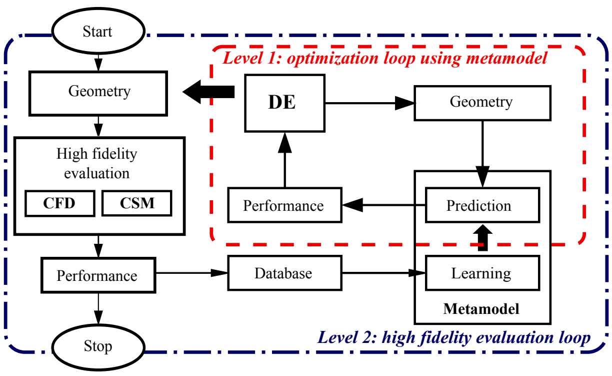


**Figure 1. Optimization system.**

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A flow chart of the optimization system used in present work is shown in Fig. 1.[1,2] The system is based on a two-level approach with a Kriging metamodel being applied as a continuously updated replacement of the computationally expensive high fidelity evaluation tools. On the first level a multi-objective Differential Evolution algorithm is used to optimize the designs solely based on the Kriging prediction. In order to assess and improve the accuracy of the Kriging metamodel, the best performing samples are automatically re-evaluated by the high-fidelity evaluation chain consisting of CFD and CSM analysis codes on the second level.

## III. Fan blade parametrization

The geometry of the fan blade is defined by parametric Bézier and B-Spline curves which specify the blade chord, blade angles, the thickness distributions at hub and tip sections and the profile stacking axis by lean and sweep. The blade metal angles at the leading edge, trailing edge and an intermediate point as well as the chord length are defined by spanwise B-Spline curves. Control points for these distributions are defined on four spanwise positions which are being fixed for three of the points at 0, 50 and 100% span. The blade thicknesses at hub and tip sections are defined by B-Spline curves. Both distributions can be scaled independently by a uniform scaling factor, therefore allowing thickness changes without altering the actual distributions. In addition, the number of blades is allowed to be modified resulting in a total of 26 optimization parameters.

## IV. Results

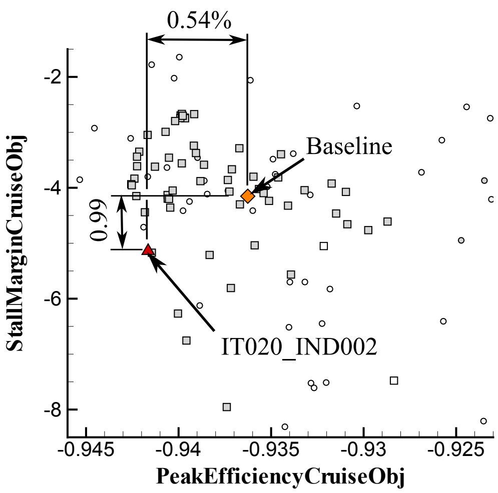


**Figure 2. Objective space after 20 iterations. Circles indicate DOE samples while squares indicate designs generated during the optimization. Deigns satisfying the constraints are shown with grey filling.**

An overview of the objective space after 20 optimization iterations (290 high-fidelity evaluations) is shown in Fig. 2. For visualization purposes the plot in Fig. 2 was scaled to show the set of feasible designs which are shaded in gray, therefore not all DOE samples are visible. For the chosen design from the Pareto front an efficiency improvement of 0.54 % and a stall margin improvement of 0.99 were obtained with respect to the baseline design.

## References


[1] Storn, R., Price, K., *Differential Evolution - A simple and efficient adaptive scheme for global optimization over continuous spaces*, Journal of Global Optimization 11 (4), 1997, pp. 341-359.

[2] Verstraete, T., *CADO: a computer aided design and optimization tool for turbomachinery applications*, in: 2nd International Conference on Engineering Optimization, Lisbon, Portugal, 2010.