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Design Optimization of the Intake of a Small-Scale Turbojet Engine

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Summary

This paper proposes a gradient-based progressive optimization technique, which can be efficiently combined with black-box simulation codes. Its efficiency relies on the simultaneous convergence of the flow solution, of the gradient evaluation, and of the design update, as well as on the use of progressively finer grids. The developed numerical technique has general validity and is here applied to the fluid-dynamic design optimization of the intake of a small-size turbojet engine, at high load and zero flight speed. Two simplified design criteria are proposed, which avoid simulating the flow in any turbojet components other than the intake itself. Using a geometrically constrained polynomial profile, both design optimizations have been produced in less than the amount of computational work to perform nine flow analyses; moreover, both optimizations have provided almost coincident intake profiles. Negligible performance improvements have been obtained by removing one geometrical constraint, at the price of almost tripling the CPU time required. Finally, the original and the optimal profiles have been mounted on the same small-scale turbojet engine and experimentally tested, to assess the resulting improvements in terms of overall performances. All numerical and experimental achievements can be extended to the intake of a micro-turbine for electricity generation. A sample of the optimization improvements is here given. The outer wall of the original geometry shows a corner between the convergent and the axial parts of the turbojet intake, which causes a separation bubble to be formed immediately downstream of the corner. As a consequence, downstream of the recirculation bubble a low total-pressure flow region can be observed, which significantly perturbs the velocity profile at the inducer inlet. At this point, the optimization procedure has been applied in order to determine an appropriate optimized intake profile, which obviously eliminates the previous corner. The corresponding Mach number contours show that t