STABILITY OF INDUSTRIAL AERODYNAMIC DESIGN OF WIDE-BODY-WING CONFIGURATION TO ITS INITIAL SHAPE

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Summary. The stability of industrial automatic multi-point constrained aerodynamic design of wide-body aircraft to the initial shape is investigated. The design is based on a recently developed robust and accurate optimization software OPTIMENGA_AERO which is driven by genetic algorithms and full Navier-Stokes computations combined with Reduced-Order-Models approach and massive multilevel parallelization. The applications include single- and multi-point aerodynamic designs for a transport-type aircraft configuration. For the considered class of shape optimizations, significant drag reduction in on- and off-design conditions has been achieved. It was shown that the optimizations which start from markedly different initial shapes ultimately converge to optimum shapes very close one from another. The paper demonstrates how automated techniques based on the developed method have now matured and provide an industrial strength solutions . The work was done under financial support by Ministry of High Education and Fundamental Investigations of Russian Federation (project RFMEFI57617X0103).

1 INTRODUCTION

In the last twenty years, CFD-driven aerodynamic shape design has drawn increased academic and industrial interest. In aircraft industry, expectations exist that the use of automatic optimizers could essentially shorten the process of aerodynamic design (especially at a stage of preliminary design, which may cost more than 100 million). It is also anticipated that accurate optimizers may improve the quality of design, making the project more competitive. A number of approaches to the problem of aerodynamic shape optimization have been proposed based on various models of flow simulation and optimum search techniques. Up to the present time, the impact of CFD driven optimization tools on practical aircraft design is rather limited still being far from matching the expectations. The following reasons may contribute to this. Many of the developed methods employ incomplete flow models such as inviscid Euler equations which may be misleading where viscous effects are significant. Many optimization methods in use for shape optimization are confined to finding a local optimum (e.g. gradient based methods). This may present a major obstacle to successful optimization since (like in many nonlinear optimization problems) the objective function under consideration has a large number of local minima. Another fundamental drawback is the inability to accurately handle large amount of constraints placed upon the optimum which is characteristic of industrial aerodynamic optimizations. Finally, in order to become industrially successful, the optimization process should be stable and automatic. This means that once the starting geometry, design conditions and constraints are set up, no time-tuning of input parameters is required, and the optimization proceeds without need in user intervention.

2 PROBLEM STATEMENT

The considered problem of aerodynamic design is solved in the stage of preliminary design prior to which the aircraft mission and aerodynamic performance parameters have been already determined. This allows to specify, alongside geometric characteristics of design, aerodynamic design conditions: cruise lift coefficient and Mach number, the maximum value of allowable pitching moment, the minimum value of allowable C_L^{max} etc. We use drag as objective function since it is a common measure in aerodynamic design being a sensitive indicator of aerodynamic performance. Problem constraints are implemented through two methods. Where possible, the constraints are satisfied in an exact way. The remaining constraints are converted into alternative constraints which are expressible in terms of drag. For example, the geometrical constraints and such aerodynamic constraints as prescribed lift coefficient are satisfied exactly while the requirement of a sufficiently high C_L^{max} at the take-off conditions is reformulated in terms of drag at the corresponding flight conditions. In order to ensure the accuracy of optimization we require that for any geometry feasible from the constraints' viewpoint, the value of the objective function should remain exactly equal to the value of the drag coefficient without any penalization (which is not easily satisfied).

The purpose of the paper is to present the results of application of OPTIMENGA_AERO software for industrial multipoint constrained aerodynamic design of wide-body aircraft wing-body configuration and to demonstrate, that this design is stable to the initial shape. This software features an efficient method for constraint handling developed for Genetic Algorithms, scanning of the optimization search space by a combination of full Navier-Stokes computations with the ROM method, and a multilevel parallelization of the whole computational framework. The designed shapes which satisfy a large number of aerodynamic and geometrical constraints and are aerodynamically feasible, yield significant aerodynamic improvement to the initial geometry at the design conditions alongside good off-design performance. It was demonstrated that the design is stable with respect to the initial shape: optimizations which start from markedly different initial shapes ultimately converge to optimum shapes which are little different one from another and have similar aerodynamic characteristics. The software tool operates in a fully automatic mode and is able to provide industrial-strength solutions that are not easily found without the use of advanced optimization software.