Hybrid Method for Aerodynamic Shape Optimization in Automotive Industry

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Octobre 2001

Abstract[1]

Decreasing the fuel consumption of road vehicles, due to environmental and selling arguments reasons, concerns car manufacturers. Consequently, improving the aerodynamism of car shapes, which implies reduction of drag coefficient, becomes one of the topic of automotive research centers. Hence, numerical shape optimization theory is applied to propose development process of a new car and innovative low-drag shapes. The main objective of this study is to set up an optimization strategy for mono-disciplinary design problem using fluid mechanics analysis.

An automatic method of optimization of aerodynamic shapes is developped in this paper based on two types of algorithms, namely a stochastic method coupled with deterministic one. The stochastic algorithms studied here are the Genetic Algorithms (GA) [1]. This technique is inspired from the Darwinian theory of improvement of species. A population of potential solution of the optimization problem are generated and evolves through the three natural principles which are selection, crossover and mutation. As this method does not require any particular regularity of the cost function, it can be applied to any optimization problem. Moreover as the GA are global methods of optimization, they seek global optima; they are also able to solve multi-objective problems and are easily parallelizable. Nevertheless, as they use a population of solutions, they require a long computational time proportional to the evaluation time of the cost function. Another drawback is that they can give good results only with a reduced number of optimization parameters.
Applied to our case, it seems that GA are too expensive in terms of simulation time. Hence, an hybrid method has been developped. It consists in coupling the GA with a deterministic gradient-based method through the following way : first a random population of solutions is improved by means of a GA. Then few steps of gradient-based method (namely the BFGS method) are applied to the best individual obtained. This new individual is replaced in the population and the GA restarts until its next improvement. The process is stopped after stabilization of the solution.
In aerodynamic applications, the main difficulty of gradient-based methods is the computation of the sensitivity of the cost function with respect to its parameters. Two types of computations

[1] Abstract for contributed talks or posters in AMIF 2002

have been experimented here : the first one is by finite differences and the second one through an incomplete sensitivity analysis at the discrete level (see [2]).

Both methods, pure GA and hybrid algorithm, have been tested, compared and validated, first with classical analytic optimization problems, then with a simple 2D aerodynamic optimization problem with 6 design variables.
The current application of this study concerns the drag reduction of a 3D simplified shape of a vehicle, called a bluff body (see Figure 1), through the optimization of the three rear angles (backlight, boat-tail and ramp angles) [3]. For a comparable level of drag reduction, the use of an hybrid method leads to significant savings in computer time compared to a pure genetic algorithm.

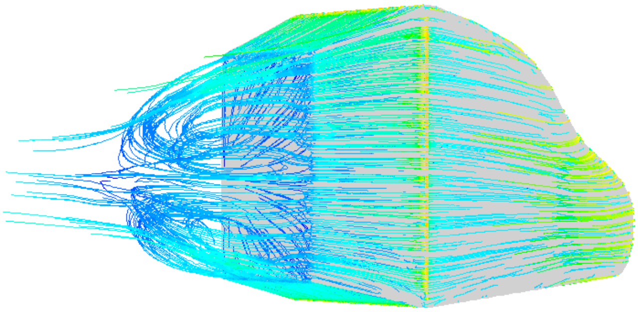

Figure 1: Pathlines colored by X-Velocity around the bluff body

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