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EXTRACTION OF PROPER ORTHOGONAL DECOMPOSITION MODES FOR OPTIMAL AERODYNAMIC SHAPE DESIGN

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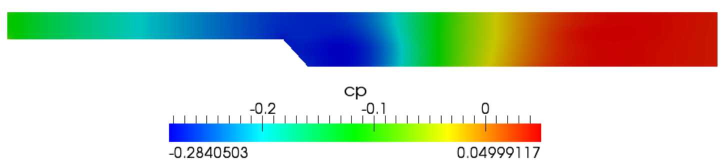
Optimal shape design of complex geometries is now a necessity in several engineering disciplines. Optimal wing design in aerospace industry and optimal vehicle aerodynamics in automotive field are two important examples. The increase of complexity of these kinds of geometries leads to a greater number of parameters to be optimized. Such a large number of variables strongly affects the efficiency of any optimization algorithm and may prohibitively increase the time needed to find an optimal solution. As an example, the need to perform hundreds of simulations to recover a representative population can be an expensive task for a genetic algorithm.

The aim of this work is to greatly reduce the computational effort required to obtain an optimal shape design of complex geometries. With this intent, the Proper Orthogonal Decomposition (POD) method has been adopted [1]. Historically, the POD procedure has been applied to time-varying problems. In this work its utilization is focused on steady fluid dynamics [2]. In order to perform the reconstruction of the fields of interest, the snapshot method, first developed by Sirovich [3], has been selected. Each snapshot is characterized by different geometrical or flow parameters and obtained from CFD simulations. Using the information contained in the snapshots, the POD method computes a set of orthogonal basis which can be linearly combined to obtain the flow field associated to any arbitrary group of parameters. The reconstruction process requires an almost negligible computing time compared to the duration of a full CFD simulation. Therefore, if the POD reconstruction is used for the function evaluations needed by a genetic algorithm, it is possible to greatly speed-up the optimization procedure.

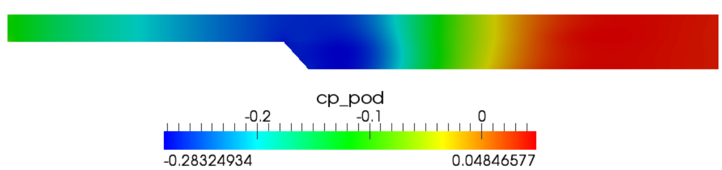
As a preliminary study, to test the capability of the POD method, the flow field past a backward facing step has been analyzed. The set of snapshots has been obtained varying the inlet flow velocity or modifying the slope α of the step. Then, the POD reconstruction has been applied to obtain the flow field for an inlet velocity or a slope not included in the initial set of snapshots. Figure 1 shows the comparison between the pressure coefficient field obtained by a conventional CFD simulation and the one obtained using the proposed POD reconstruction procedure with four snapshots.

In the second part of the work, a multi-parameter optimization of a full vehicle has been performed, exploiting the POD reconstruction procedure combined with a genetic algorithm. The aim of the analysis was to reduce the drag coefficient of the base configuration modifying the geometry of the car. Figure 2 shows the comparison between the CFD field and the POD reconstructed field of the pressure coefficient.

In conclusion, the POD method can be applied not only in time, but in every parametric space of interest, saving a great amount of computational effort. The POD modes are sufficient for the reconstruction of the function evaluations required from the genetic algorithm and further investigation of this method can be foreseen.

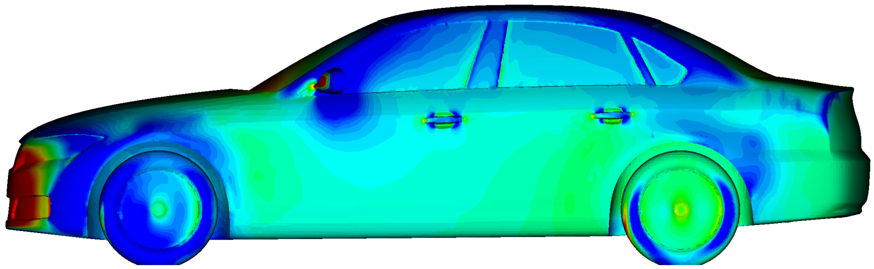


(a) Pressure coefficient field obtained from CFD simulation

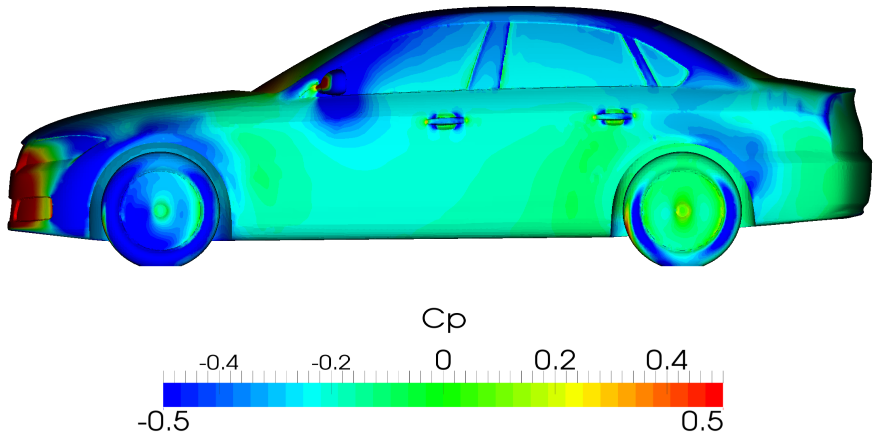


(b) Pressure coefficient field obtained from POD reconstruction

Figure 1: *Visualization of the results of the POD reconstruction for the pressure coefficient field-*α = *48 deg*



(a) Pressure coefficient field obtained from CFD simulation



(b) Pressure coefficient field obtained from POD reconstruction

Figure 2: *Visualization of the results of the POD reconstruction for the pressure coefficient field-optimization of a full vehicle*

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