Application of the POD method to optimal design of experiment

Wojciech Gryglas*[1], Lukasz Laniewski-Wollk[1], Bartosz Olszanski[1], and Piotr Szaltys[1]

[1]*Institute of Aeronautics and Applied Mechanics, Warsaw University of Technology, ul. Nowowiejska 24, 00-665 Warszawa*
wgryglas@meil.pw.edu.pl

Both the measurement domain and the sensor cost usually limit the number of measurement devices. Therefore, one of the most crucial problems during experimental setup is to distribute a limited number of sensors optimally. For this task, we propose instrumentation methodology based on a reduced model built with the Proper Orthogonal Decomposition (POD)method. The reduced model must predict measured phenomenon for the range of all permissible flow parameters, e. g.: different angle of attack or inlet velocities. Therefore, it necessary to perform set of numerical simulation which would supply the model with required data. The number of CFD calculations can be large nevertheless they can be performed in parallel with minimal human interaction. Having the reduced model allows performing optimization for sensors locations. The optimization process is based on covariance minimization by utilizing A-criterion. The Fisher Information Matrix (FIM), required for computing A-criterion, is computed based on the POD model. As the result, optimal sensors locations are being obtained that minimize measurement uncertainty. Additionally, having the phenomenon model, it is possible to reconstruct whole flow field basing only on data gathered from sensors.

The above methodology was applied to the problem of selecting pressure sensors on the VKI-LS59 turbine blade cascade. The reduced model ware built up from 200 different CFD simulation, what covered a range of different angles of attack and inlet Mach number. As the result of the optimization process, 11 positions were selected out of 69 available, see Figure 1. Afterwards, the experiment was conducted and the pressure values in all 69 positions ware collected. The data gathered only from 11 optimal sensors locations together with prepared reduced model allowed to reconstruct pressure profile around the whole blade. This result was then compared with values obtained from all 69 sensors (Figure 2). The comparison has shown good agreement what confirmed the possible application of the proposed methodology for a broad range of fluid dynamics experiments.

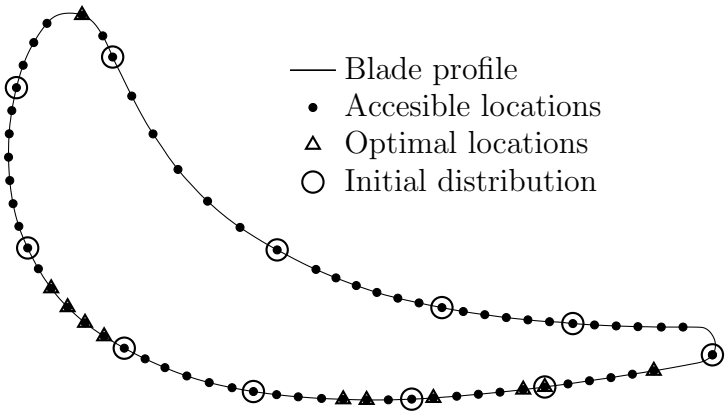

Figure 1: Optimized measurement locations

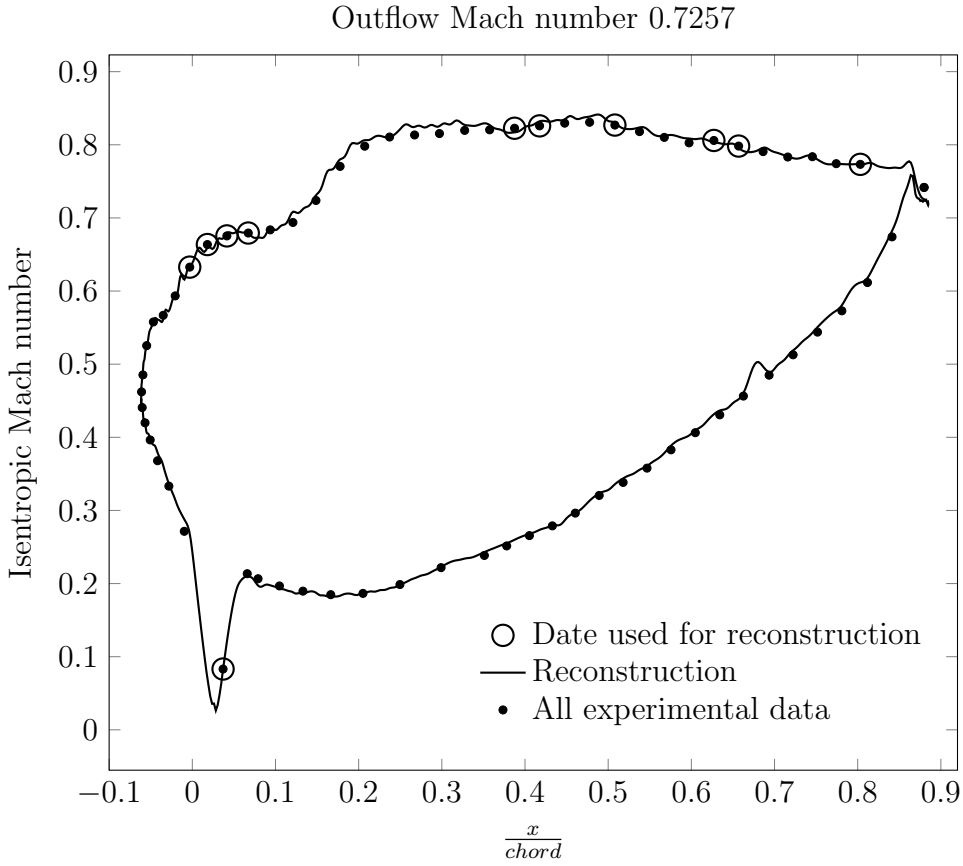

Figure 2: Comparison between reconstructed and experimental isentropic Mach number profile