Numerically Closing the Loop of the Adaptive Optics Sensor: The Validation of the COMSOL Multiphysics® Simulation

C. Del Vecchio[1], R. Briguglio[1], A. Riccardi[1]

[1]National Institute for Astrophysics, Arcetri Astrophysical Observatory, Florence, Italy

Abstract

As any other modelling of a physical behavior, the numerical simulation of the mechanical response of an adaptive secondary mirror requires that the results match the experimental data. Achieving such an agreement, recently demonstrated for the actuator forces of the LBT and VLT Deformable Mirrors, also for the shell displacements makes the numerical simulation results a self-consistent set of data on which the control commands may rely on. Moreover, thoroughly reliable modelling avoids to set up the complex optical measuring equipment required by the convex shells and complicated analyses at the mirror inner and outer edges. Finally, accurate numerical data make easier the calibration. For all these reasons, the accuracy of the numerical results is of vital importance. Therefore, the methodology of the comparison with the experimental data must be properly selected.

The feedback signal of the actuator of the adaptive optics control system is provided by a capacitive sensor - the displacements is proportional to the capacitance variation. The experimental data are supplied by means of an interferometer as deformation maps. The substantial difference between the model and the physical system is that in the latter the displacements are measured on the annular areas of the capacitive sensors, co-axial with the magnetic force vector, while in the model the displacements are measured directly on the magnet locations. The closed loop ensures that the applied command is equal to the measured position, read on the above mentioned surface. As the system and the model read at different locations, the displacements are obviously different. The implementation of the actual reading on the model is computational overwhelming, so that we identify a matching strategy to transform the model output into data compatible with the actual measures.

After a discussion about the methods adopted to collect the measurement data, this paper shows the numerical procedures selected to run the simulations. Specifically, two key points are emphasized. Firstly, the method chosen to approximate the evaluation of the capacitance variation by computing the displacements along a circumference: the effectiveness of the method is demonstrated by a model refinement. Secondly, the shell mesh strategy which provides a relevant reduction of the computational time: a proper, unusual mesh allows an enough accuracy with a relatively small number of elements. Finally, the correlation of the experimental data and the numerical results is demonstrated. In particular, the comparison of the measurement fitting and

of the numerical result fitting are discussed, in order to define the calibration procedure.

As a results, closing the loop without any optical measure is now suitable because of the results of the COMSOL Multiphysics® computations along with the pyramid wavefront sensor acquisitions.

The methods disclosed in this paper demonstrate that COMSOL Multiphysics® is fully capable to replicate the measures, even the delicate gauges provided by the capacitive sensors. Properly implementing some computational algorithms in the Structural Mechanics Module and carefully meshing the shell domain allows to defines with enough precision the full set of data required by a completely numeric, highly accurate control system.

Figures used in the abstract

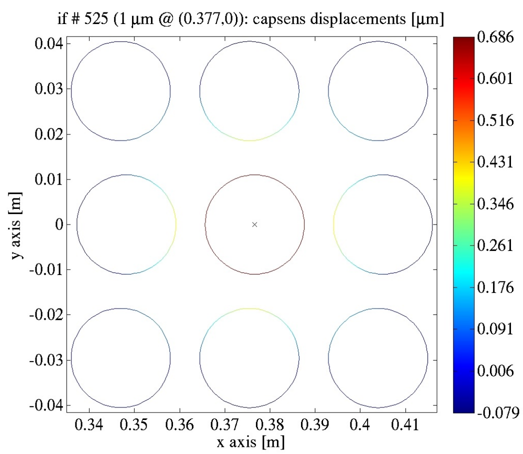

Figure 1: The capsens displacements: a typical example

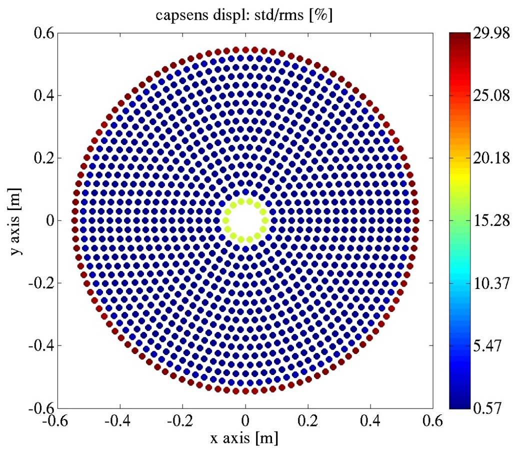

Figure 2: Capsens displacements: the overall accuracy

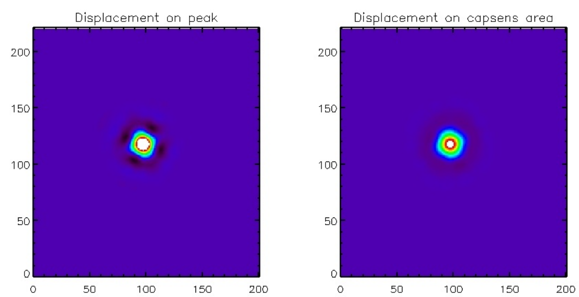

Figure 3: Comparison of the model output and the transformed one