OPTIMIZATION OF HEAT TRANSFER UNDER UNCERTAINTY

E. Nobile[1§], A. Clarich[2], C. Poloni[1]

(1) Dip. Ingegneria e Architettura, Università degli Studi di Trieste, 34127 Trieste ITALY

(2) ESTECO S.p.A., AREA Science Park, Padriciano 99, 34149 Trieste ITALY

(§) Corresponding author. Email: nobile@units.it

SUMMARY

The standard approach, when solving thermofluids problems numerically, is to prescribe the geometry, boundary conditions, and thermophysical properties, and solve the governing equations for velocity, pressure, temperature, turbulent kinetic energy, etc. Problems of this type are referred to here as analysis problems.

In design practice of thermally active devices and systems, like e.g. heat exchangers and heat sinks, the engineer usually tries different geometries, chooses other materials with different properties, et., until satisfactory performance is obtained. Such cut-and-try method relies on the experience and skill of the designer to obtain any improvement, and optimal performance is rarely achieved. This simple approach, however, becomes impractical when the number of design variables is large, when there is more than one objective, and there are several constraints to be satisfied. Therefore, it is mandatory in such cases to adopt an optimization strategy as illustrated by Ranut et al. [2014]. However, in most heat transfer applications, some values of the input design parameters are not known or it is impossible to know their exact value. For example, uncertainties could characterize some geometric entities (lengths, relative positions,...) that concerns to the problem studied; many times the operating conditions are not fixed, but there is the presence of fluctuations: for example the values of inlet mass flow and heat flux are affected by such uncertainties. In these circumstances, traditional optimization techniques tend to "over-optimize", producing solutions that perform well at the design point, but have poor off-design characteristics. This problem, although well known in the i.e. aeronautical design community or in fluid dynamics - see e.g. Hicks and Vanderplaats [1977] and Parussini et al. [2010] - to the authors best knowledge it has been considered only recently in the heat transfer community, see Bodla et al. [2013] and Sarangi et al. [2014].

In this lecture, after a review of the state-of-the-art of Optimization under uncertainty for heat transfer applications, it will be illustrated how the Uncertainty Quantification (UQ) can be combined, using an advanced adaptive polynomial chaos methodology, with Robust Design - Multi Objective Robust Design Optimization (MORDO) - and Design for Reliability. While the former focusses upon the robustness of the solution, i.e. the stability of an optimization outcome against the variations in the input parameters, the latter considers the probability that a certain design will not fail to meet a predefined criterion or performance function. Two relevant multiobjective examples will be considered: the geometry design and sizing for the air-side of a compact heat exchangers, and the geometry definition of an offset strip-fin microchannel heat sink. For both examples it will be also illustrated how the computational burden can be dramatically reduced exploiting sensitivity analysis, in order to reduce the number of design variables and/or limiting the uncertainty quantification to the most significant ones, and replacing, within the optimization, the time-consuming CFD model with Response Functions (surrogates).

References

Ranut P., Janiga G., Nobile E. and Thévenin D., [2014], Multi-objective shape optimization of a tube bundle in cross-flow, *Int. J. of Heat Mass Transfer*, vol. 68, 585–598.

Hicks R. M. and Vanderplaats G. N., [1977], Application of numerical optimisation to the design of supercritical airfoils without drag-creep, *SAE Paper 770440*, Business Aircraft Meeting, Wichita, USA.

Parussini L., Pediroda V., Poloni C., [2010], Prediction of geometric uncertainty effects on Fluid Dynamics by Polynomial Chaos and Fictitious Domain method, *Computers & Fluids*, Vol. 39 (1), pp. 137-151.

Bodla K. K., Murthy J. Y. and Garimella S. V., [2013], Optimization Under Uncertainty Applied to Heat Sink Design, *ASME J. Heat Transfer*, Vol. 135, pp. 011012-011012-13.

Sarangi S., Karthik Bodla K. K., Garimella S. V. and Murthy J. Y. [2014], Manifold microchannel heat sink design using optimization under uncertainty, *Int. J. Heat Mass Transfer*, vol. 69, pp. 92–105.