NON-PARAMETRIC SHAPE OPTIMIZATION IN INDUSTRIAL CONTEXT

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ABSTRACT

Non-parametric[1] shape optimization has its roots in the work from Zienkienwicz et al. [17] in 1973. In 1979 Schnack [15] published a sensitivity-free optimality criteria method for shape stress optimization which was the basis for TOSCA Structure.shape [10, 14] which even today solves difficult industrial non-parametric shape optimization problems. The TOSCA Structure technology is now also available in Abaqus/ATOM[6] and in NX 8.0[16] which makes the setup of non-parametric optimization easy for even optimization novices. The main advantage of non-parametric shape optimization is the ease of setup, avoiding tedious parametrization that may be too restrictive with respect to design freedom. One of the major disadvantages on the other hand is that the CAD-interpretation of the shape optimization result is not trivial.

Non-parametric sensitivity based shape optimization has gotten a boost the last 5 years especially due to work from Daoud and Firl [5, 7]. The use of filters [5] inspired from checkerboard control in topology optimization[3] showed to be a simple, but effective, remedy to avoid jagged mesh solutions. The sensitivity analysis must be efficient and flexible which the semi-analytical exact sensitivities [7, 9] is for structural problems.

Shape optimization for fluid problems is currently only available within a small number of specialized CFD solvers with minor industrial impact, in spite of the fact that the underlying theory is well known[11]. For industrial important CFD solvers[1, 2, 12, 4] the research in the field of sensitivity based optimization strategies has just recently started. A commercial implementation of an adjoint sensitivity calculation has been announced by ANSYS Fluent for the near future version R14[8], where a parameterization approach can be used to update the geometry. A continuous adjoint approach implemented in OpenFOAM[13] is currently the only applicable solution for industrial non-parameteric optimizations, regardless of its disadvantages like for instance the complicated inclusion of turbulences into the gradient calculation.

Current presentation is going to show some of the current trends within non-parametric shape optimization with a special focus on the industrial context. Thus, we emphasize on easy setup of the non-parametric shape problem and we will show large scale shape optimizations with many design variables as well as many degrees of freedom solved in CAE-environments that are typical for an industrial analyst. Due to the large number of design nodes in most non-parametric optimizations the adjoint method for sensitivity calculation is exclusively used. The examples will be followed with short discussions about whether or not the optimizations could have been done with ordinary parametric shape optimization. At the end some closing thoughts about future developments within non-parametric shape optimization.

[1] Optimization parameters are the nodal position, but in CAD terminology these are not parameters

1. REFERENCES

[1] Ansys Inc. *CFX Manual*, 13.0 edition, 2011.

[2] Ansys Inc. *Fluent Manual*, 13.0 edition, 2011.

[3] M. P. Bendsøe and O. Sigmund. *Topology optimization: Theory, methods and applications*. Springer-Verlag Berlin, Heidelberg, 1st edition, 2003.

[4] CD-Adapco. *Star-CCM+ Manual*, 6.0 edition, 2011.

[5] F. Daoud. *Formoptimierung von Freiformschalen, Mathematische Algorithmen und Filtertechniken*. PhD thesis, Chair of Structural Analysis, TU Munich, 2005.

[6] Dassault Systèmes, Simulia. *Abaqus Manual*, 6.11 edition, 2011.

[7] M. Firl. *Optimal Shape Design of Shell Structures*. Dissertation, Technische Universität München, Mnchen, 2010.

[8] Genong Li and Chi-Yang Cheng. Mesh morphing and the adjoint solver in ansys r14. In *ANSYS Conference Boston*, 2011.

[9] E. Lund. *Finite Element Based Design Sensitivity Analysis and Optimization*. PhD thesis, Institute of Mechanical Engineering, Aalborg University, 1994.

[10] R. Meske, J. Sauter, and E. Schnack. Nonparametric gradient-less shape optimization for real-world applications. *Structural and Multidisciplinary Optimization*, 30:201–218, 2005. 10.1007/s00158-005-0518-0.

[11] Bijan Mohammadi and Olivier Pironneau. Shape optimization in fluid mechanics. *Annual Review of Fluid Mechanics*, 36(1):255–279, 2004.

[12] OpenCFD Ltd. acquired by SGI. *OpenFOAM*, 2.0 edition, 2011.

[13] C. Othmer, E. de Villiers, and H.G. Weller. Implementation of a continuous adjoint for topology optimization of ducted flows. In *AIAA*, 2007.

[14] J. Sauter. Caos oder die suche nach der optimalen bauteilform durch eine effiziente gestaltoptimierungsstrategie. In *Internationaler Finite Elemente Kongress, Baden-Baden, University of Karlsruhe*, 1991.

[15] E. Schnack. An optimization procedure for stress concentrations by the finite element technique. *International Journal for Numerical Methods in Engineering*, 14:115–124, 1979.

[16] Siemens Product Lifecycle Management Software Inc. *NX Manual*, 8.0 edition, 2011.

[17] O.C. Zienkiewicz and J.S. Campbell. Shape optimization and sequencial linear programming. *Optimum Structural Design*, pages 109–126., 1973.