8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

LARGE SCALE OPTIMIZATION BASED ON ADAPTIVE METAMODELLING

Andrey A. Polynkin[1] and Vassili V. Toropov[2]

[1] Research Fellow
University of Leeds, Leeds,
West Yorkshire, LS2 9JT, UK
a.polynkin@leeds.ac.uk

[2] Professor of Aerospace and Structural Engineering
University of Leeds,
Leeds, West Yorkshire, LS2 9JT, UK
v.v.toropov@leeds.ac.uk
www.personal.leeds.ac.uk/~cenvvt/

Key Words: *Adaptive Metamodelling, Mid-range Approximations, Ttrust Regions*

ABSTRACT

This work is focused on addressing large scale design optimization problems (that may contain hundreds of design variables) by the use of a mid-range approximations [1,2] that has been originated in early 1980s and undergoes continuous development [3-7]. Such a technique replaces the original optimization problem by a succession of simpler mathematical programming problems. The functions in each iteration present mid-range approximations (an adaptive metamodel) of the original functions. These metamodels are computationally inexpensive and noise-free. The solution of an individual sub-problem becomes the starting point for the next step, the move limits (that define a current trust region) are changed and the optimization is repeated iteratively until the optimum is reached. Each metamodel is defined as a function of design variables as well as a number of tuning parameters. The latter are determined by the weighted least squares surface fitting using the original function values (and their derivatives, when available) at several points of the design variable space. This selection of points is treated as a design of numerical experiments. Some of the design points are generated in a current iteration, and the rest is taken from the pool of points considered in the previous iterations.

The procedure described above utilizes intrinsically linear functions [8]. Such functions are nonlinear, but they can be led to linear ones by simple transformations. These functions include a multiplicative function, an inverse function, a power function, etc.

A new approach is being investigated in the attempt to produce new high quality approximations valid for a larger range of design variables that is based on the use of rational approximations that are a particular class of functions nonlinear in unknown coefficients. Due to rapidly growing number of coefficients for large number of design variables (that is the main objective of this work), the function structure has to be limited to low degree polynomials (e.g. linear) and small datasets. Results of extensive numerical testing show that, although the linear form of the rational approximation describes the global behaviour of a highly nonlinear response rather poorly, such

approximations proved useful in the mid-range approximation framework.

In the present work the developed technique has been applied to the shape optimization of an existing transonic compressor rotor blades (NASA rotor 37) treated as a benchmark case. Simulations were performed using the CFD software [9].

The authors are grateful to the UK Department of Trade and Industry, Rolls-Royce plc and Airbus UK Ltd for the support of this work.

REFERENCES

[1] Toropov, V.V. Simulation approach to structural optimization. Structural Optimization, vol. 1, pp. 37-46, 1989

[2] Toropov, V.V., Filatov, A.A., and Polynkin, A.A. (1993). Multiparameter structural optimization using FEM and multipoint explicit approximations. Structural Optimization 6:7-14

[3] van Keulen, F., Toropov, V.V., and Markine, V.L. (1996). Recent refinements in the multi-point approximation method in conjunction with adaptive mesh refinement. In McCarthy, J.M., ed., Proceedings of ASME Design Engineering Technical Conferences and Computers in Engineering Conference, Irvine, CA: 96-DETC/DAC-1451. 1-12.

[4] Toropov, V.V., van Keulen, F., Markine, V.L. and de Boer, H. Refinements in the multi-point approximation method to reduce the effects of noisy responses. 6th AIAA/NASA/ISSMO Symp. on Multidisciplinary Analysis and Optimization, Bellevue WA, September 1996, Part 2, pp. 941-951, AIAA, 1996

[5] van Keulen, F., and Toropov, V.V. (1997). New developments in structural optimization using adaptive mesh refinement and multi-point approximations. Engineering Optimization 29:217-234.

[6] Toropov, V.V., Markine, V.L., and Holden, C.M.E. (1999). Use of mid-range approximations for optimization problems with functions of domain-dependent calculability, Proceedings of 3rd World Congress of Structural and Multidisciplinary Optimization, Buffalo, NY.

[7] Toropov, V.V., van Keulen, F., Markine, V.L. and Alvarez, L.F. Multipoint approximations based on response surface fitting: a summary of recent developments. In: V.V. Toropov (ed.), Proc. of 1st ASMO UK / ISSMO Conf. on Engineering Design Optimization, Ilkley, July 8-9, 1999, pp. 371-380, MCB University Press, 1999

[8] Box, G.E.P., and Draper, N.R. (1987). Empirical model-building and response surfaces. New York: John Wiley and Sons.

[9] Lapworth. B.L., Shahpar, S. (2004). Design of gas turbine engines using CFD, ECCOMAS 2004, July 24 – July 28, 2004.