Options NSGA2 in practice

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About OptionsNSGA2

OptionsNSGA2 is a multiobjective optimization tool that has been developed in the Computational Engineering and Design Group since 2005. It attempts to meet the increasing demand for solving a variety of optimization problems, where more than one goal needs to be searched simultaneously. The tool is based on the NSGA2 approach, pioneered by Prof. Kalmonoy Deb and the OptionsMatlab suite developed by Prof Andy Keane and the e-Science centre at Southampton. By combining these two powerful packages, adding various improvements, substitutions and new functionality, OptionsNSGA2 has become the preferred tool for an increasing number of researchers and development groups inside and outside Southampton University. Acknowledgements are made to Rolls-Royce, Derby, as this tool has been developed with their sponsorship.

Modes of Operation

Direct OptionsNSGA2 provides an easy but flexible interface for engineers to set up their optimization problems in various environments and platforms. Those who like the flexibility of MATLAB can use the tool directly in MATLAB, while others can run it without many prerequisites directly from the command prompt or embed it in various integration tools such as iSIGHT.

The real strength of this package, however, is demonstrated when used with Response Surface Methods – the OptionsNSGA2_RSM version. Using this version it has become possible to run a complex robust design structural optimization of a Whole Engine Model, on a single Tech-PC within two days. The significance of this achievement is obvious if compared to a direct optimization which would take over 6 months and therefore was never thought feasible. The general idea is presented in **Fig.1**. Heavy optimization runs are carried out on a response surface model, which is continuously updated until convergence with the Finite Element code is obtained.

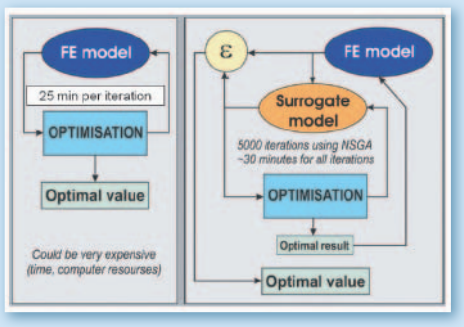

Fig.1 Optimization using surrogates

The OptionsNSGA2_RSM tool was originally developed to design an engine structure which is robust to external loads variations (**Fig.2**). In order to evaluate the variability, at each optimization iteration 200 right-hand structural solves were needed. Each colour on **Fig.2** represent group of elements, combined in a super-element. Fifteen of these were varied, minimizing four objectives – mass, SFC (specific fuel consumption), variance of reaction forces and mean of reaction forces.

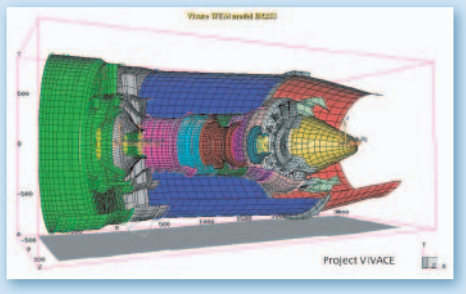

Fig.2 VIVACE Whole Engine Model

The tool has been applied to reduce SFC and mass by altering the thickness of the intercase of a T1000 engine. Following this success, it is now planned that OptionsNSGA2_RSM will be used at several stages in the development of the new XWB engine.

Quick facts about OptionsNSGA2 and OptionsNSGA2_RSM

- Based on OPTIONS, NSGA2, OptionsMatlab and Matlab.
- Works under Windows, Linux and Unix
- Direct and Response Surface versions
- Selection of five update strategies for the response surface model
- Selection of 15 response surface models
- Options for user tuning and customized settings
- Parallel tuning techniques
- Parallel function evaluations
- Can be easily restarted from a specified checkpoint
- Can use continuous or discrete variables

Achievements to date

- Optimization with 356 variables (Andy Keane, Shahrokh Shahpar)
- Optimization with 19 objective functions (Neil Bressloff)
- Optimization with 100 discrete variables (Charalambos Tsatsaris)
- Compiled as a standalone application and deployed in Rolls-Royce (Ivan Voutchkov)

Applications

- Whole Engine robust optimization (Ivan Voutchkov)
- T1000 SFC and MASS optimization (Ivan Voutchkov)
- Earth system modelling (GENIE) (Andrew Price)
- Discrete multiobjective optimization (Charalambos Tsatsaris)
- Guide vane optimization (Andy Keane, Ivan Voutchkov)
- Blade wall thickness analysis and core shape optimization (HIPARSYS) (Ivan Voutchkov, Tony Scurr – **Fig. 3**)
- Vibration isolation structures (Alexander Forrester – **Fig. 4**)
- Robust shape optimal design (Appu Kumar – **Fig.5**)
- Manufacturing cost optimization (Abhi Rao – **Fig.6**)

Further work

OptionsNSGA2 is being continuously refined. The ability to used more variables with the RSM approach as well as further methods for solution quality improvement are currently being investigated. Work is ongoing to apply and deploy the tool with various teams in Rolls-Royce.

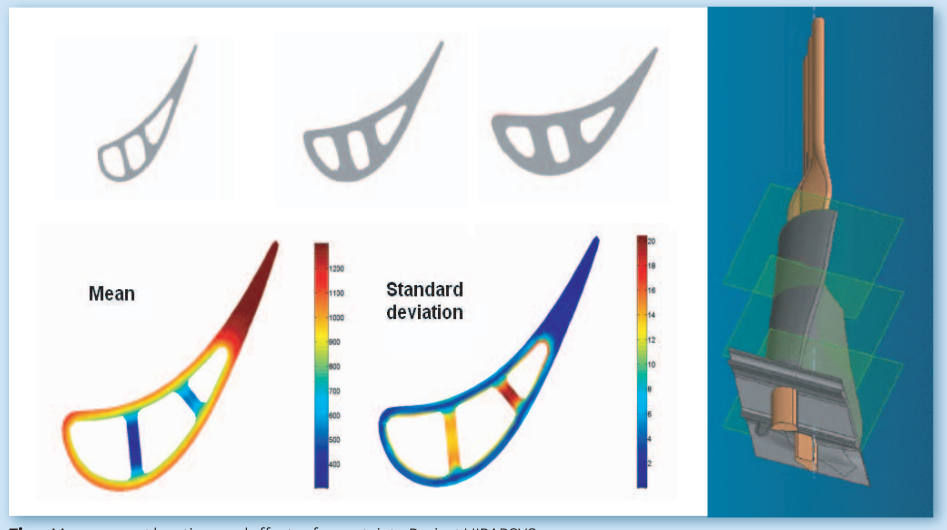

Fig.3 Measurement locations and effects of uncertainty. Project HIPARSYS.

"The two objectives were vibration isolation and number of beam intersections. We are forced to pick the design with zero intersections, so the Pareto front is not really used, but NSGA-II has proved to be the best way to optimize the structure. Fewer than 0.02% of designs have zero intersections, so it's a difficult problem."

Dr. Alexander Forrester

Fig.4 Vibration isolation structure. Picture: © Dr. Forrester

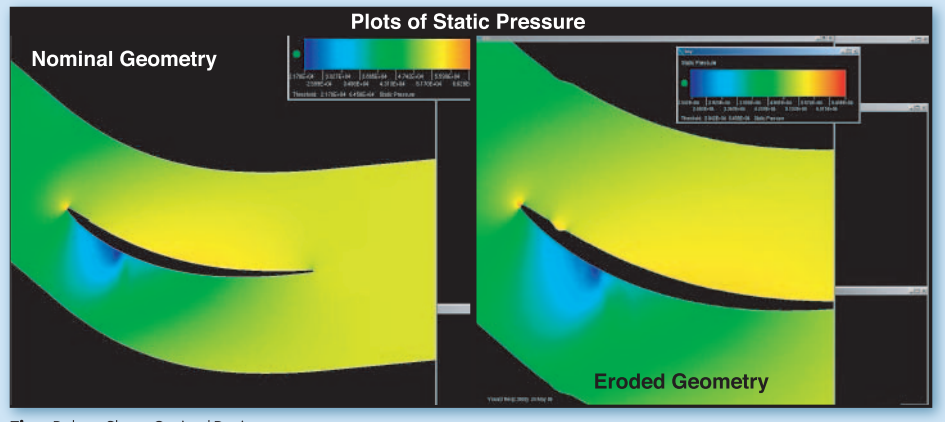

Fig.5 Robust Shape Optimal Design

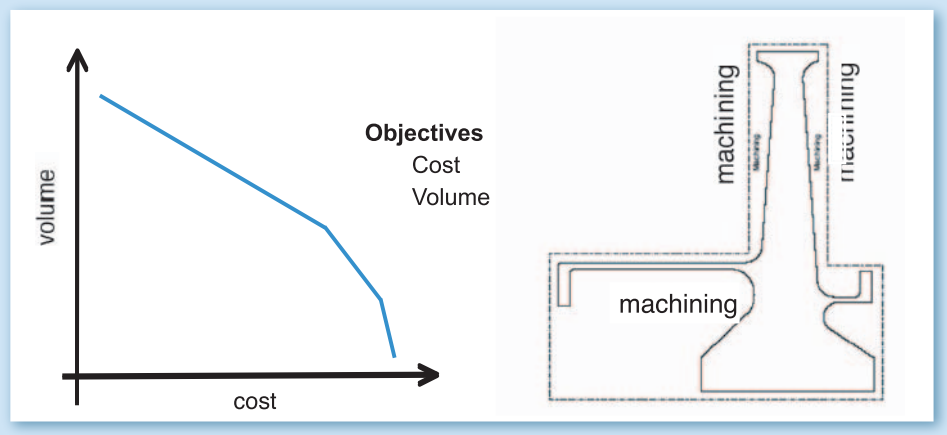

Fig.6 Manufacturing cost optimization

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