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Robust optimization of the Life of turbine blades – an automated approach

UTC for Computational Engineering
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Objectives

- To increase the robustness of turbine components through improved design.
- To implement multi-objective CAD and optimization based robust design tools that allow for uncertainties in the manufacturing process.
- To deploy new robust design tools based on existing desktops (UG, SC03, iSight) and and train staff in their use.
- To use manufacturing data on geometric uncertainties in constructing analysis models.
- To investigated the use of manufacturing data in design search and optimisation.

Achievements to date

Robust workflow in standard Rolls-Royce working environment (iSight-FD) – The workflow shown in Figure 1, represents a complex sequence of existing and newly developed tools, stitched together and deployed in the Rolls-Royce working environment. The workflow can be used on its own or deployed in more complex workflows. The aim of this sequence is to manipulate the shape and position of the blade core to provide a wide variety of alternative designs.

✓**Using tools of various nature and origin** – The workflow incorporates various codes – such as NX4, Parasolid Export, Cadfix, SC03. Although all of these tools are ready for automation, significant effort was required to ensure that all tools communicate with each other seamlessly. The development of the worklflow started in iSIGHT v.10 and mid-project, after the release of iSIGHT-FD the workflow had to undergo a complete rework. The new platform provided more stability and flexibility of both the development process and the final product.

✓**New Optimization Components** – The robust design and optimization nature of the project required new optimization techniques to be integrated in the iSIGHT framework. OPTIONS, OptionsMatlab and OptionsNSGA2_RSM are optimization packages developed in Southampton with proven record of solved problems and agility. They have been successfully used in a number of other design and optimization projects in Rolls-Royce. During the current project they were further developed and incorporated inside the iSIGHT workflow engine. They now appear as separate optimization methods – OPTIMATFD and OPTIMATFD-RSM – see Figure 2.

✓**Innovative core deformation technique** – One of the major challenges in this project was to find a way to limit the number of geometry control variables, whilst producing a good spread of designs. The conventional method required manipulation of large amount of CAD information – spline coefficients, point coordinates, etc. The number of variables exceeded 200 which reduced its usability for the purposes of optimization and robust design studies. An innovative approach, called Free-Form Deformation (FFD) was used instead – see Figure 3. In summary – instead of moving each CAD element individually, the designer can choose an arbitrary number of control points which when moved would affect the position of all the neighbouring elements, depending on their distance to that particular control point.

✓**Statistical analysis of experimental data** – In order to be able to conduct a successful robust design study, we needed to have representative data about the variation of the blade wall thickness during production. By conducting Gauge Repeatability & Reproducibility analysis we were able to obtain two components of the variation – due to gauge measurement error and due to manufacturing. Some important conclusions were made in the process about the measurement and inspection procedure and recommendation on improving these were passed to the inspection staff during a series of meetings and link calls.

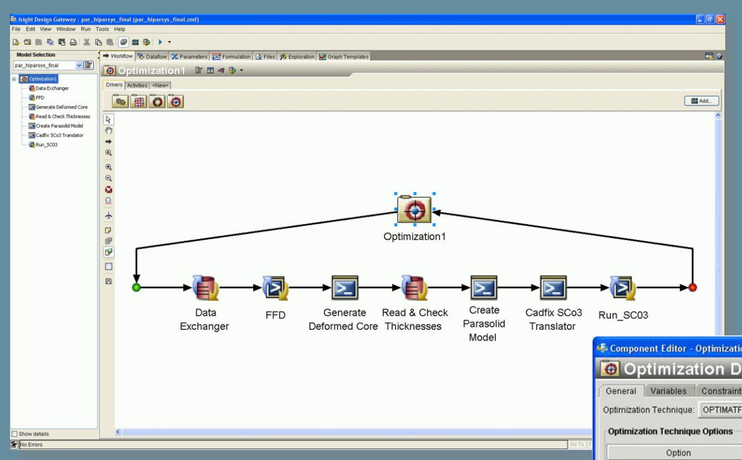

Figure 1 – Computes the life of a blade in relation to the shape and position of the core.

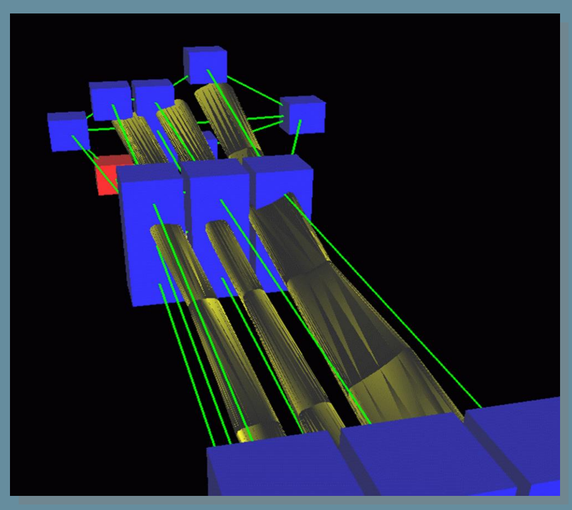

Figure 3 – Free Form Deformation uses control points to manipulate the core.

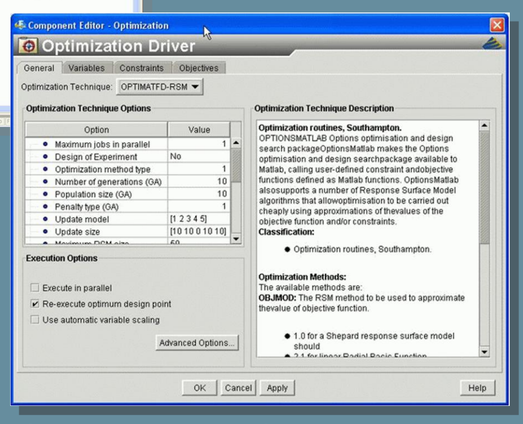

Figure 2 – OPTIMATFD and OPTIMATFD_RSM are integrated in iSIGHT-FD

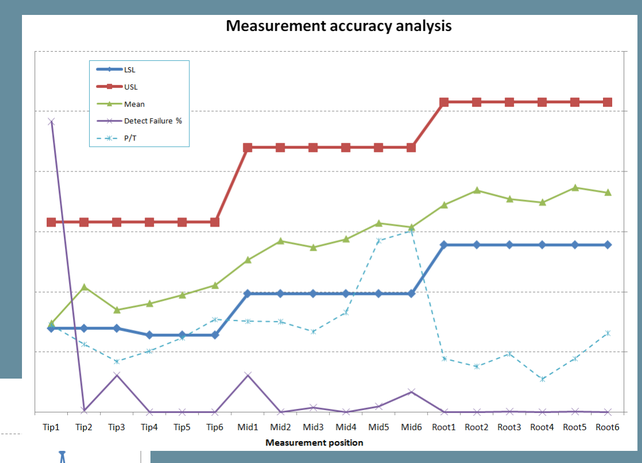

Figure 4 – Variance components

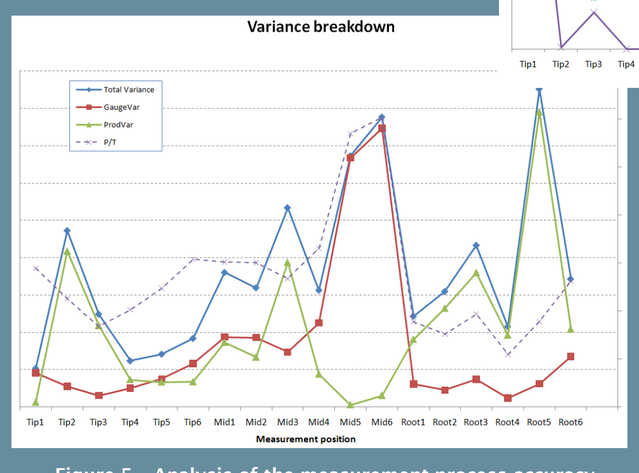

Figure 5 – Analysis of the measurement process accuracy

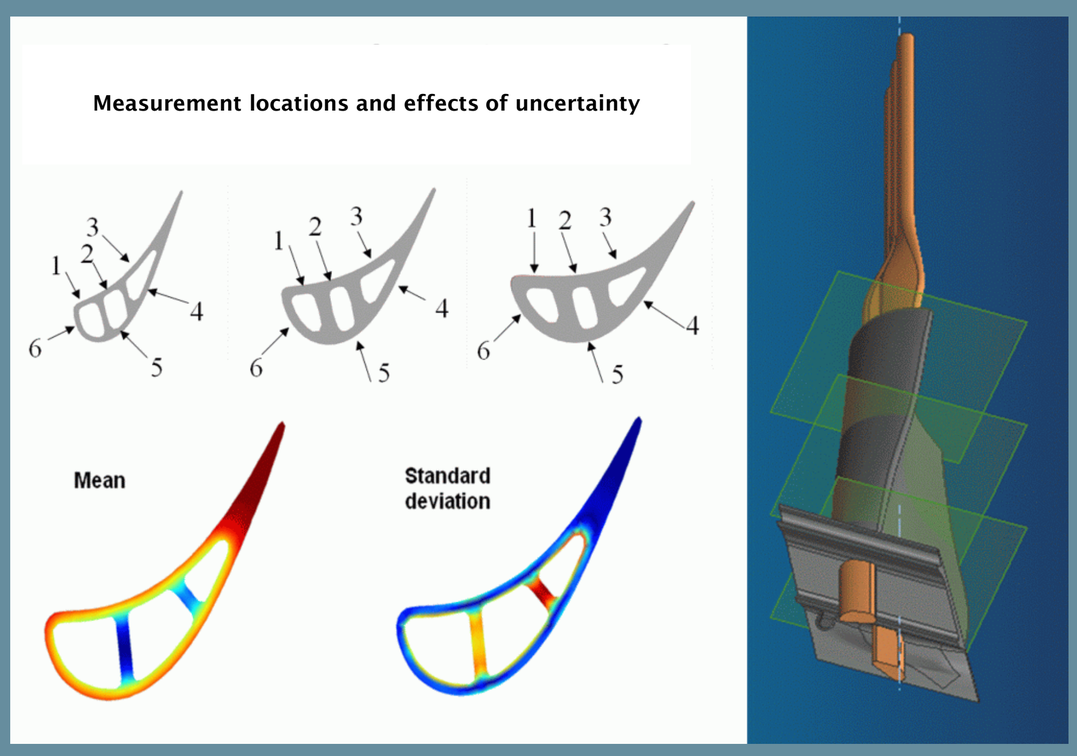

Figure 6 – Robust design of the life of the blade

Future work

The tools and knowledge gained during this project provide a solid platform for future development and integration of robust design and optimization techniques. Currently the workflow is being used to conduct Monte Carlo simulations on the life of blades and to find the shape of the core that would make the blade least sensitive to manufacturing errors – see Figure 6. The Optimization methods mentioned above are under constant development and new versions will appear in the iSIGHT version after testing. Development of new plug-ins is also underway – for example the stochastic solver plug-in to SC03, which is expected to reduce significantly the number of function evaluation required to estimate the mean and standard deviation.

HIPARSYS HIGH PERFORMANCE AND ROBUST SYSTEMS

The work presented here is part of the HIPARSYS project (http://hiparsys.ecs.soton.ac.uk/)

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