Optimization of a Tail Bearing Housing Component

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The Research

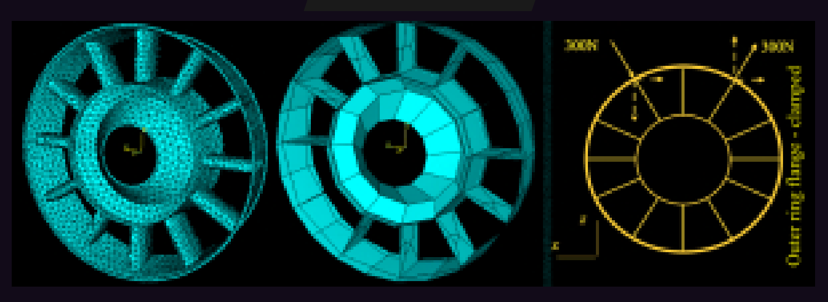

Fig. 1: Fine and coarse meshes, boundary conditions and loads.

The aim of this research is to reduce the weight of a gas turbine Tail Bearing Housing (TBH) component, while not exceeding given stress or displacement constraints at any location on the structure. The loads and boundary conditions have been supplied by manufacturers that are participating in the European Union MMFSC programme – ITP, Rolls-Royce, Volvo, Snecma. The geometry CAD model is prepared by Queen's University of Belfast.

The Structure and the Tools

The optimization goal is achieved by varying the thicknesses of sheet elements on the structure. Twelve variables have been identified – 7 vanes, outer ring, inner ring and 3 inner ring configuration surfaces.

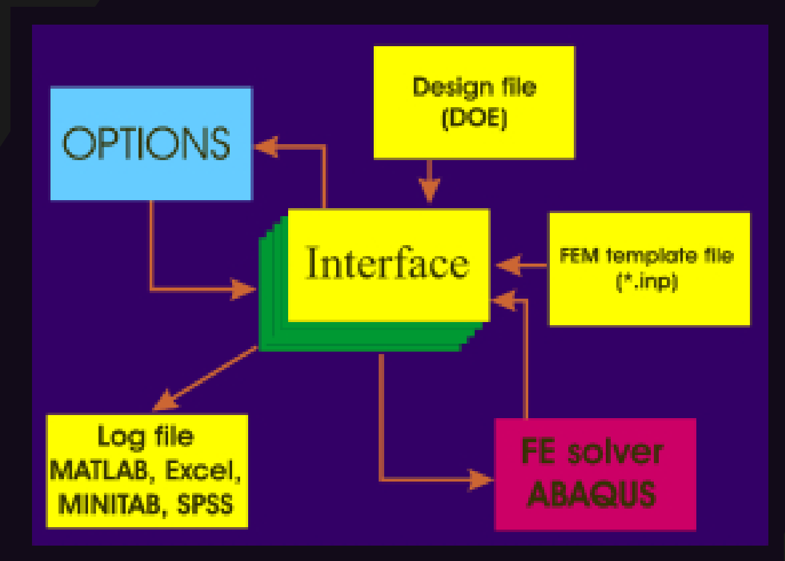

Fig. 2: Software interface link.

ABAQUS is used as the main finite element solver, while OPTIONS is the package used for optimization. Both packages have been linked through a collection of FORTRAN subroutines, specifically developed for this task, which also contained a Kriging modeling routine. The interface allows full automation of the optimization procedure, using a queuing system to manage parallel session computations.

Kriging – GA hybrid

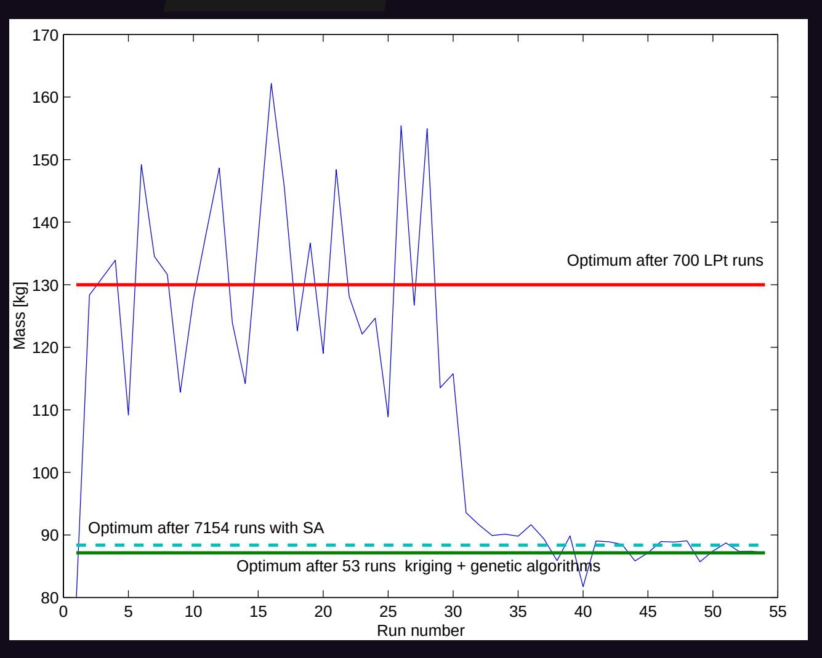

Fig. 3: Kriging-GA hybrid optimization.

Various methods, that are available in OPTIONS, have been used. The best results were achieved using Simulated Annealing (SA) or Genetic Algorithms (GA). Both converged to the global minima after 8000 function evaluations. Other methods had problems converging to the global minima. Evaluations were performed on a more coarsely meshed FE model, to reduce the computational expense. Then a hybrid approach was used. The weight, stresses and displacements at a predefined node and element were modeled using Kriging, followed by a GA optimization. At the resulting optima, a fine meshed FE model was evaluated, and the result added to the kriging model, again followed by a GA optimization. This sequence was repeated until convergence of the value being found by the GA was achieved. As a result the thicknesses satisfying the constraints and minimizing the weight were obtained in only 53 fine meshed FE model evaluations, 24 of which arose during optimization and 29 during the initial runs to build the Kriging model.

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Constraints selection procedure

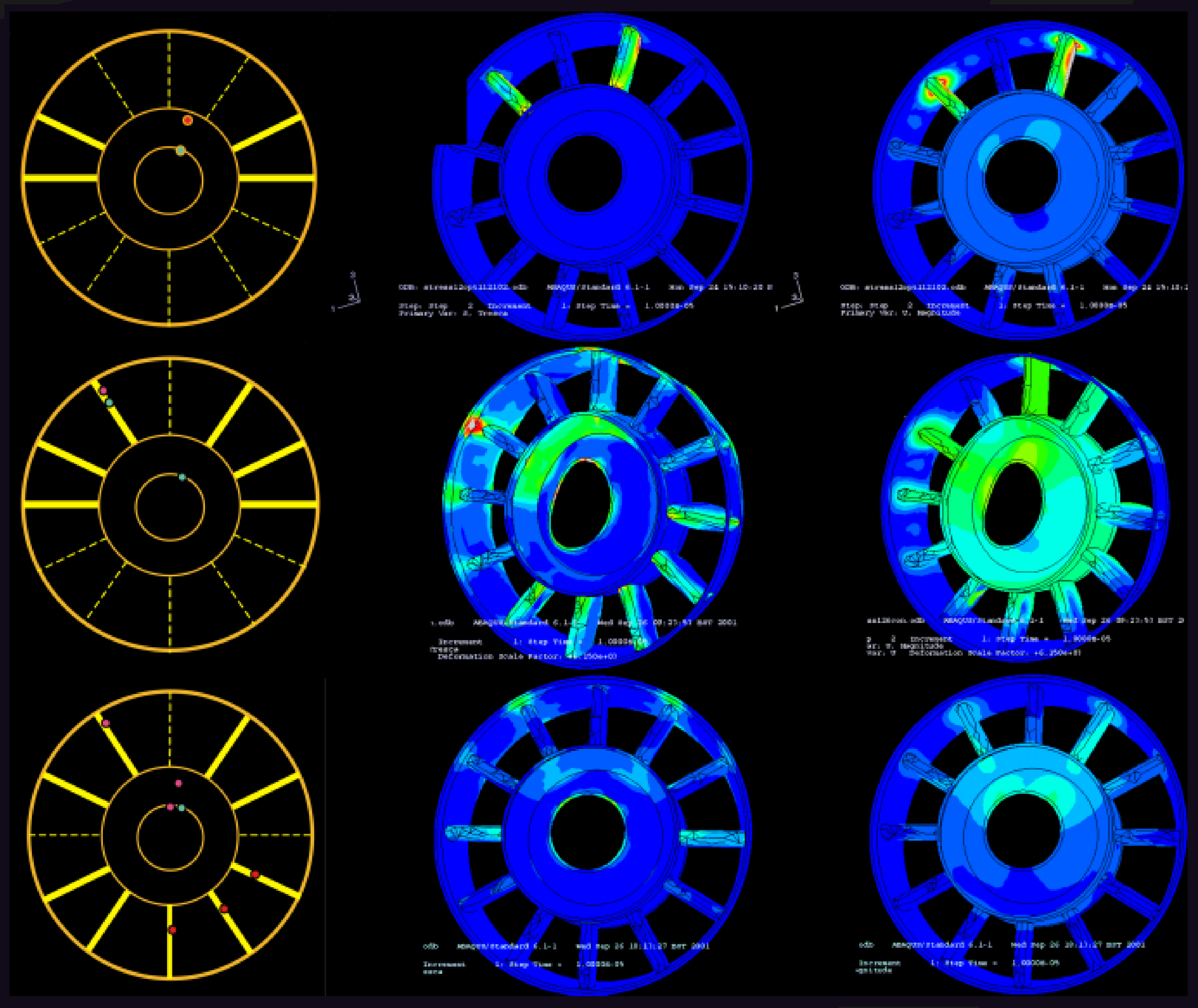

Fig. 4: Three-stage constraint selection.

It is not feasible to use as a constraint the maximum stress on the structure, since with every design combination, the location of this value may vary. Constraints should be measured at fixed location through out all designs. The results obtained so far, satisfied one stress and one displacement constraint. As a result an uneven stress distribution occurred. At the points of high stress and displacement values, four new constraints were added, and the structure was re-optimized, using additional 23 runs.

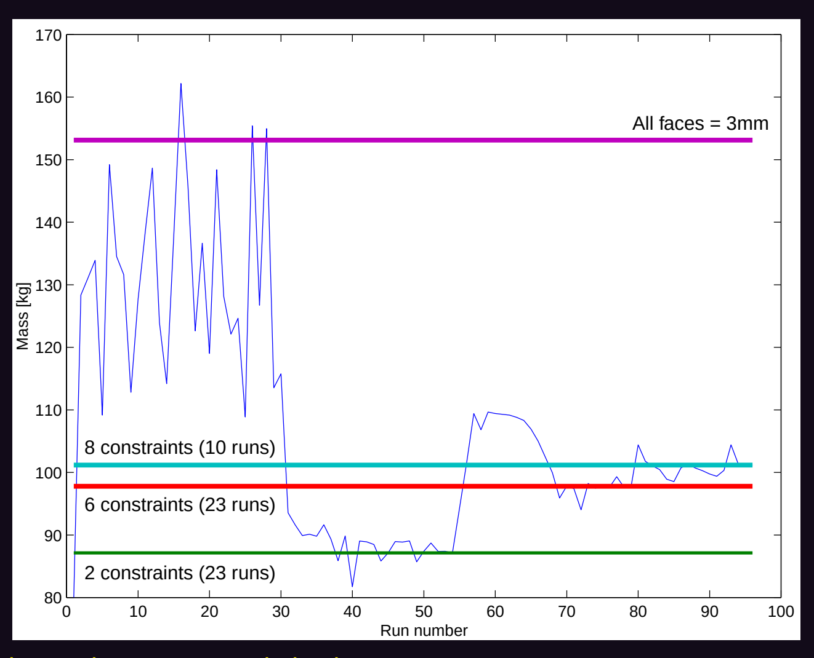

Fig. 5: Three-stage optimization convergence process.

At the new highest stress and displacement locations another 2 constraints were added and the design again re-optimized with an additional 10 runs, producing a structure with a much more even stress distribution. The final structure is 40% lighter than the original design, in which all variables were equal to 3mm. The result was obtained using 86 fine meshed FE model evaluations in total. If the constraints key points were known in advance, the results would have been achieved after 53 runs in total, which is a significant reduce from the 8000 runs needed by direct GA or SA optimization.

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