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Engineering and the Environment

Aeronautics, Astronautics and Computational Engineering

Whole Engine Design Optimisation Within The CRESCENDO Project

UTC for Computational Engineering

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CRESCENDO Project Overview

Collaborative and Robust Engineering using Simulation Capability Enabling Next Design Optimisation, or **CRESCENDO**, is a pan European project funded by the Seventh Framework Programme of the European Union. Approximately 59 industrial and academic partners are involved in the development of a Behavioural Digital Aircraft (BDA) with the aim of improving the efficiency and agility of the overall design process. The UTC for Computational Engineering is specifically involved in the development of multidisciplinary optimisation processes, parametric geometry and surrogate modelling tools to support cross partner trade-off studies.

Whole Engine Thermo-Mechanical Optimisation - S2T3

Thermal aircraft test case S2T3 aims to demonstrate the effective utilisation of a 3D transient whole engine thermo-mechanical model (figure 1) within a design optimisation framework. Employing such a high fidelity model within the preliminary design stage aims to effectively manage the risk of significant design changes later in an engine programme.

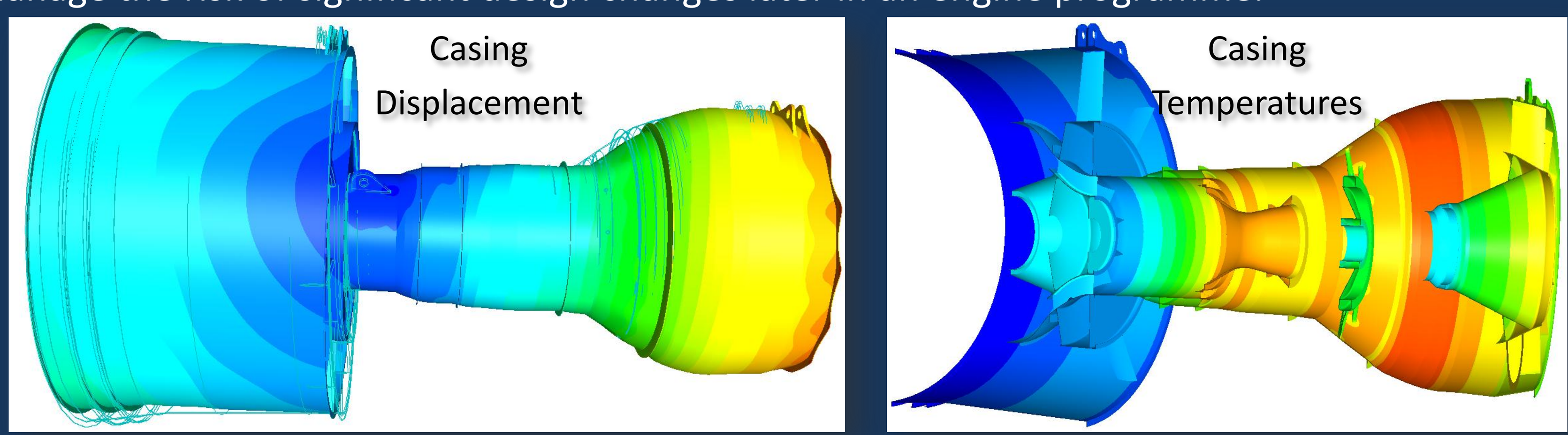

Figure 1: 3D Transient Thermo-Mechanical Analysis

To facilitate the casing optimisation, a parametric model of the CRESCENDO engine intercasing and fan casing was developed using the NX Open C API. This model (figure 2) is capable of producing a variety of modifications including, thrust link and fan mount positions, casing thicknesses, as well as the inclusion of multiple additional, fully parametric, stiffening rings.

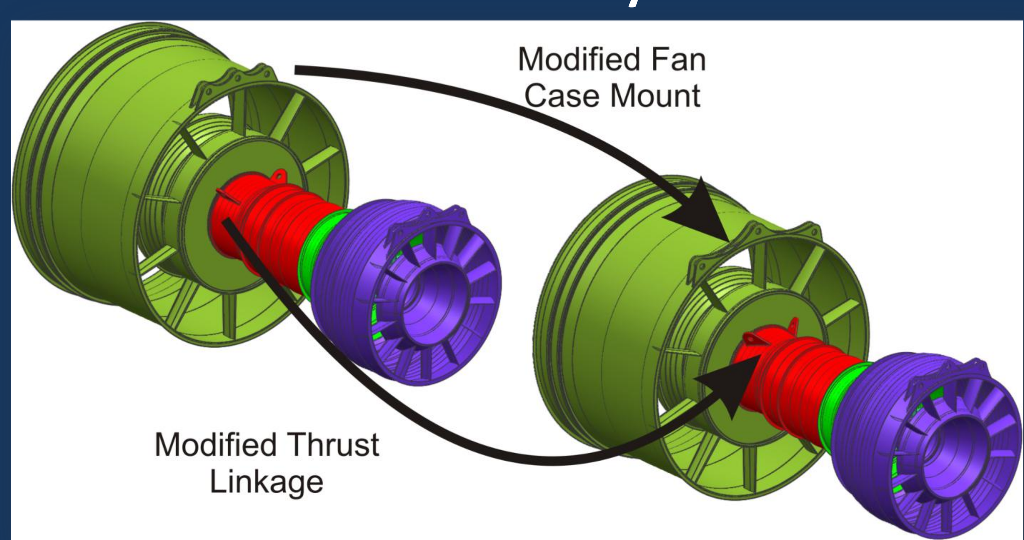

Figure 2: NX Open C Parameterisation

The expense of the simulations involved necessitate a surrogate modelling based approach within the optimisation. To this end both Kriging and Co-Kriging have been employed to create surrogate models of the objective function (the effective running clearance at cruise). Co-Kriging models allow information from multiple levels of simulation fidelity to be used in the creation of a surrogate model resulting in greater accuracy. Figure 3, for example, illustrates that a Co-Kriging model constructed using 4 high fidelity, transient thermo-mechanical simulations and 28 low fidelity, steady state mechanical simulations, is more accurate than a Kriging model created using 10 high fidelity simulations.

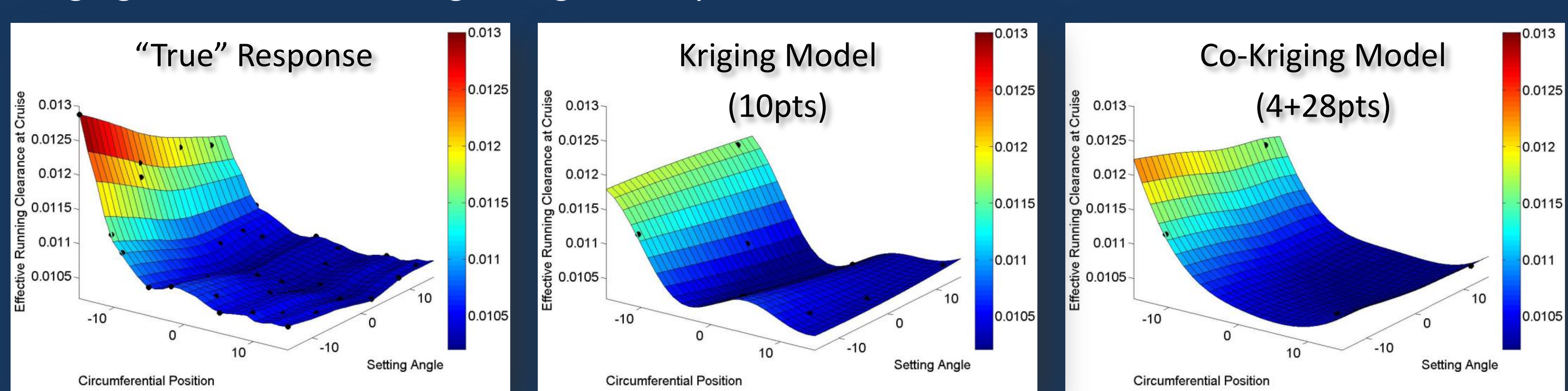

Figure 3: Comparison of 2D Kriging & Co-Kriging Models to "True" Response

Surrogate Models of Nodal Responses

As part of the wider CRESCENDO project, S2T3 is expected to provide information to other partners to enable cross-partner trade-off studies. Surrogate models can be used to share such information without ceding access to proprietary information or software. To demonstrate the feasibility of this process surrogate models were created which predict external casing temperatures and displacements of the CRESCENDO engine. Figure 4, for example, illustrates the accuracy of a prediction of the Z displacement at cruise for an unknown cooling air mass flow.

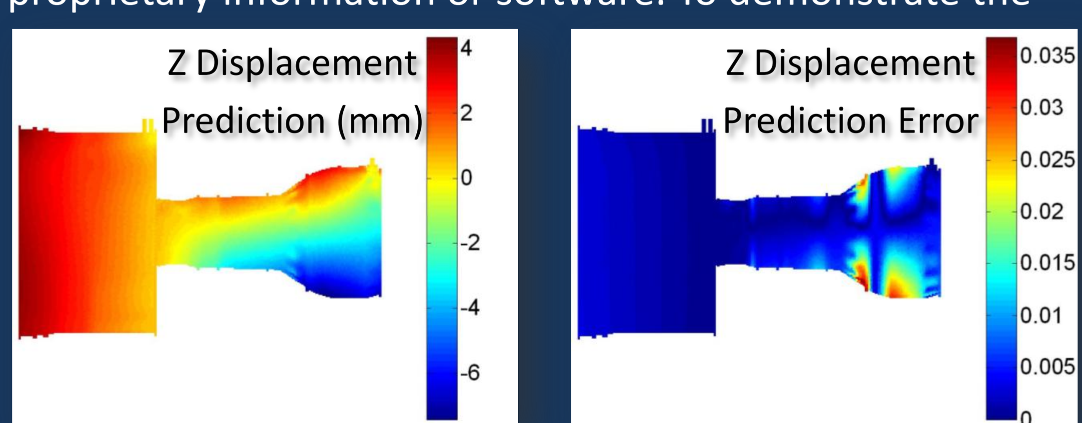

Figure 4: Prediction of Casing Z Displacement

Multidisciplinary Rotor Optimisation - S2P1S4

Scenario 4, of power plant integration test case S2P1, focuses on demonstrating the multidisciplinary design optimisation of the CRESCENDO engine rotor. In this test case the rotor, pictured in figure 5, is optimised for rotordynamics performance and effective running clearance at cruise (the same objective function used in S2T3) with constraints on the rotor mass and maximum Von Mises stresses in the various rotor components.

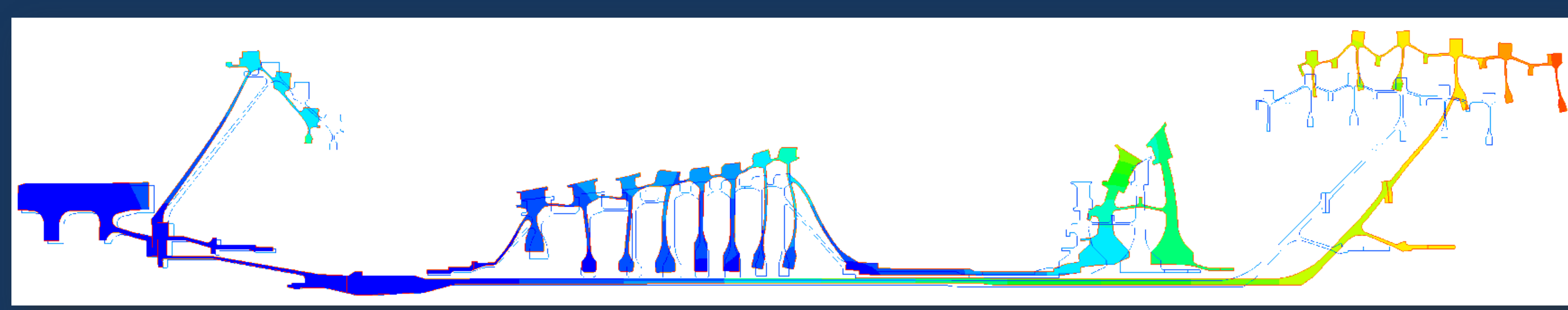

Figure 5: CRESCENDO Rotor Resultant Displacement

Using a similar process to that used within S2T3, a parametric model (see figure 6) of the HP compressor drum has been created which permits variations in the cone angle and shaft and cone thicknesses. The resulting geometry undergoes a 2D transient thermo-mechanical analysis using SC03. Von Mises stresses are calculated along with the rotor mass while the displacements are used in conjunction with the S2T3 casing model to calculate the effective running clearance at cruise.

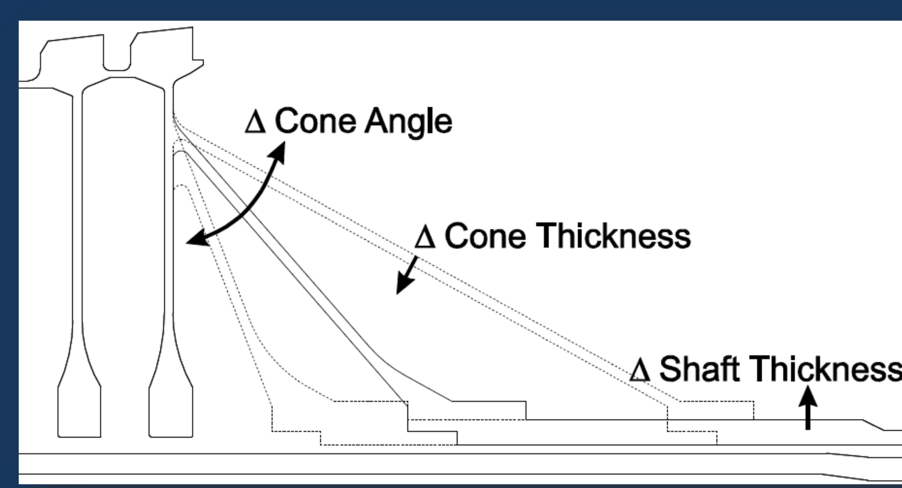

Figure 6: Rotor Parameterisation

Nodal temperature data from the thermo-mechanical simulation is used within a SAMCEF rotordynamics simulation of the modified geometry. The critical speeds are then calculated with the goal of maximising the separation between the avoidance band and the critical speed.

Once again a surrogate modelling approach is used with the optimisation process controlled via the OPTIMAT-RSM plug-in for Isight. A Latin hypercube sampling plan of the rotor design variables is constructed and the objective functions and constraints then calculated. Kriging models are created for each objective and constraint and then searched for good designs. Figure 7 illustrates the variation in effective running clearance at cruise for changing cone angle and thickness. Infeasible regions due to violations in either the limits on the rotor mass or Von Mises stresses are left blank.

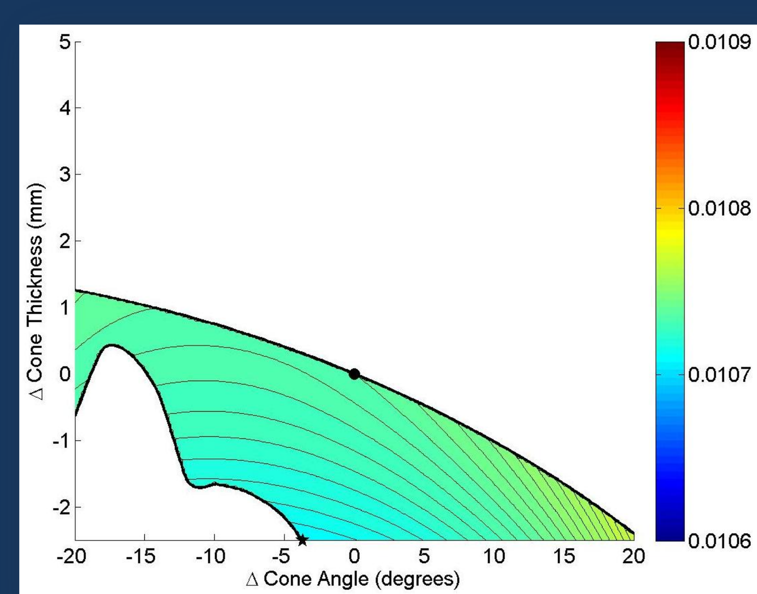

Figure 7: Rotor Design Space

Future Work

- Combine test cases S2T3 and S2P1S4 into a single multidisciplinary design optimisation incorporating high fidelity 3D transient thermo-mechanical simulations of the engine casing and 2D thermo-mechanical and rotordynamics simulations of the rotor.
- Consider more complex optimisations of the rotor and casing via the inclusion of additional geometric variables, for example, the inclusion of bosses on the intercasing or variations to the geometry of the HP compressor disks.
- Continue the development of novel surrogate modelling techniques e.g. non-stationary Kriging.

Acknowledgements

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