Supersonic Civil Transport Design Using Collaborative Optimization

Abstract for NAL Workshop on Numerical Simulation Technology for The Design of Next Generation Supersonic Civil Transport

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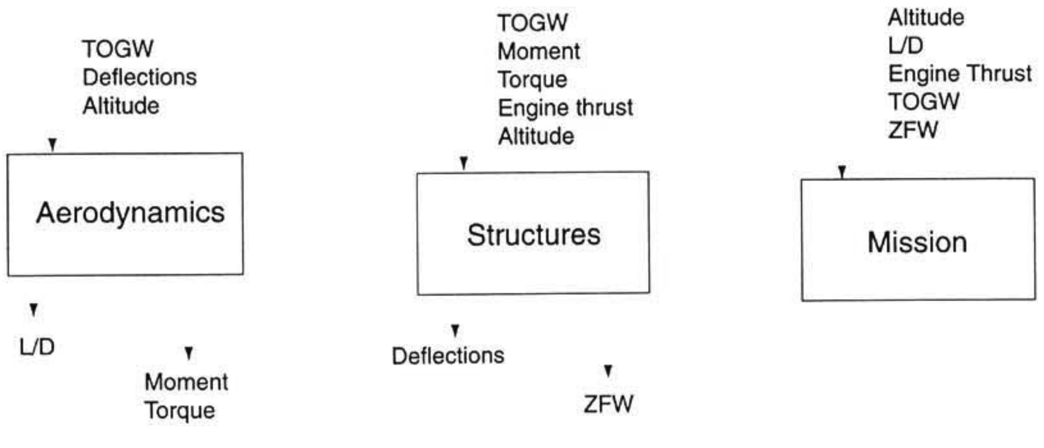
This paper describes the application of collaborative optimization, a strategy for distributed design, to the optimization of two supersonic civil aircraft concepts. This design approach permits design tasks to be decomposed into domain-specific subproblems, and coordinated to achieve an optimal system. Developed over the past few years by researchers at Stanford, NASA, and Boeing, the methodology is now being applied to large-scale problems requiring high-fidelity modeling. The paper describes one of these applications, the preliminary design of supersonic transports, and provides preliminary results for both a conventional design and a novel natural laminar flow concept.

In these design problems, a fully aeroelastic optimal solution is obtained using high fidelity industry codes for aerodynamics, a finite element structural analysis, and a mission simulation. Each of these disciplines accomplishes design tasks in parallel, at geographically distributed locations on heterogeneous computing platforms. Results are synthesized by a higher level system optimizer which is able to reduce take-off weight using 14 system-level design variables, while the subspace optimization includes dozens of additional variables used to satisfy local constraints. The basic decomposition is shown in the figure below.



Decomposition of subproblems in collaborative design of SST

Aerodynamic analysis is based on Boeing's A502 code, which provides inviscid lift, drag, moment, and pressures used for structural optimization. For the NLF concept, an additional analysis to estimate transition location is used. This new method includes both Tollmein-Schlichting and cross-flow transition mechanisms in a rapid turnaround, design-oriented code. Structural optimization is based on a finite-element analysis, developed at NASA Langley and refined by Stanford researchers. Mission analysis includes simple estimates of balanced take-off and landing field length, engine-out climb performance, and cruise range.

The interdisciplinary coupling, including aerodynamic loads and structural deflections are coordinated by a system level optimizer and modeled using a reduced basis representation. Pressures are integrated to determine torsion and bending distributions which are fit with a smaller number of spline control points. Results of each subspace optimization are fit using response surface techniques and the system-level optimization operates on this model.

The resulting process permits system-level optimization appropriate for advanced design while incorporating high fidelity subspace design. This system was implemented on a network of workstations at Stanford and NASA Langley. Results illustrate the convergence of this process, yielding a minimum weight feasible design.

The system was then applied to the design of a new SST concept employing extensive natural laminar flow. We present preliminary results of this optimization and recent results demonstrating the feasibility of this low sweep, thin wing design.