Effect of scaling of Design Variables in FFD case aerodynamic optimization

Aerodynamic shape optimization involves complex geometric analysis and a large number of design parameters. In design optimization, large order of differences in either the variable or function value can produce ill-conditioned matrices which makes algorithm calculations unstable or inefficient that leads to the poor convergence.

In this study, the scaling of 345 geometric design variables (15 spanwise locations with 22 section shape variables and 1 twist variables) and 1 angle of attack (AOA) design variable for FFD (free form deformation) case was examined which are used to address the large difference between the order of magnitude of variables. The study was performed on NASA's CRM wing model. The study was performed in two parts - one with Mach number of 0.85 and other with 0.4 to compare the difference in speed of convergence. The process involves optimizing the wind for lower drag coefficient. Thus, the parameters of lift and drag coefficient and lift to drag ratio were monitored.

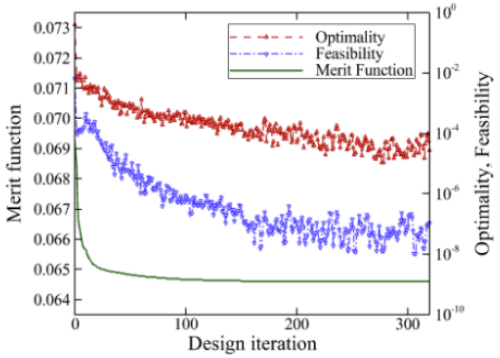


Figure 1: Convergence of L0 unscaled case

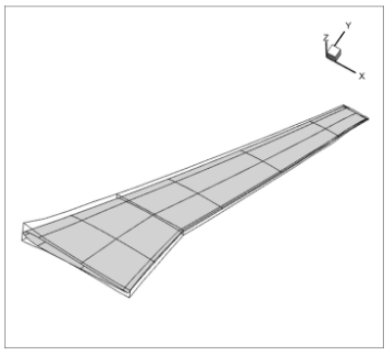
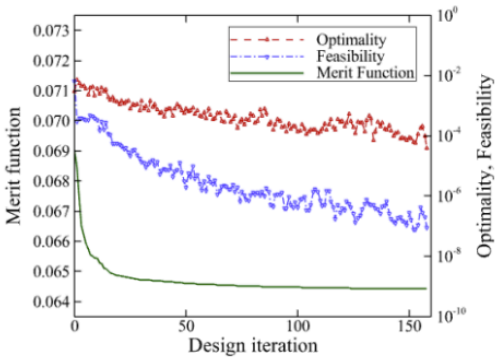
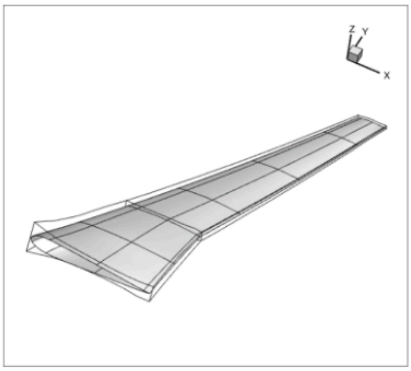


Figure 2: Shape of wing for L0 case

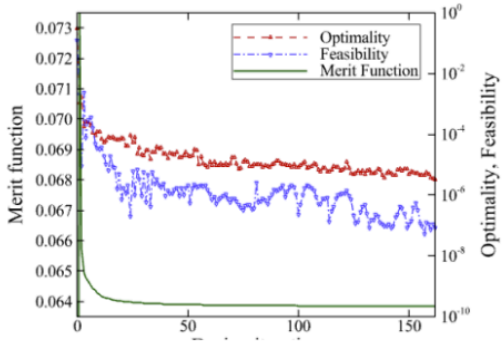
Convergence scenario for Unscaled Case with Mach 0.85

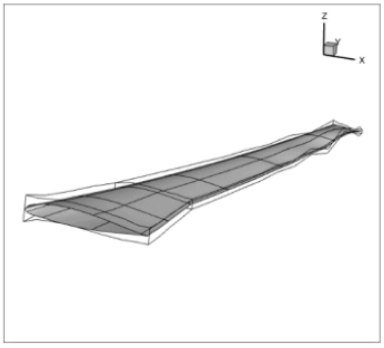




Convergence scenario for Mach 0.85 with scale factor of 0.1 to twist variables

It was observed that the cases having relatively higher sensitivity (higher scaling) to section shape variables compared to twist variables gives better and faster convergence. For Mach number of 0.85, reducing the sensitivity of the twist variables by factor of 10 compared to the unscaled section shape variables gives 83% faster convergence while for Mach number of 0.4, it gives 76% faster convergence. The scaling of AOA does not have much effect on the convergence speed for the cases.





Convergence scenario for Mach 0.4 with scale factor of 0.1 to twist variables

But it largely affects the value of AOA to which it converges. Reducing the sensitivity of the AOA variable by a factor of 10 does not allow the variable to explore the design space and stuck the variable to its initial value.